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The ART of DIALLING,

Performed

GEOMETRICALLY, by *Scale and Compasses* :
ARITHMETICALLY, by the *Canons of Sines and Tangents* :
INSTRUMENTALLY, by a *Trigonal Instrument*.

The *Geometrical Part* whereof is performed by *Projecting* of the *Sphere* in
Plano, upon the *Plan* it self, whereby not only the *Making* but the
Reason also of *Dials* is *Discovered*.

A second way of *Geometrical Dialling* very *Easie*, *Plain* and *Universal*.

The *Third Edition*.

To which is added A

SUPPLEMENT; SHEWING,

How by *Scale and Compasses* to inscribe such *Circles* of the *Sphere* into *Sun Dial-Plans*, that shall shew (besides the hour of the day) the *Diurnal Motion* of the *Sun*; his *Place* in the *Zodiack*; the *Time* from his *Rising* and *Setting*; *Babylonian*, *Italian*, and *Jewish Hours*; the *Point* of the *Compass* upon which the *Sun* is at any *time* of the *Day*, and the *Proportions* of *Shadows* to their *Heights*.

ALSO,

A *General* and *Easie* way to *Project Hour-Lines* upon all kinds of *Superficies*, without any regard had to their *standing*.

AND,

How from a *Glass Horizontally* Placed in the *Soyl* of a *Window*, to reflect *Hours* upon any *Superficies*.

By WILLIAM LEYBOURN, *Philomath*.

L O N D O N :

Printed for *Thomas Braddyl*, and Sold by the *Booksellers* of *London* and
Westminster. M D CC.



T O T H E

R E A D E R.

THIS Treatise of Dialling (*as in the former Edition*) consisted of Three Parts: the Acceptance it hath found, encouraged me to add a Fourth Part; namely, [A Second Way of Geometrical Dialling] which is performed with great Ease and Exactness, and may be serviceable to the ingenious Practitioner, when the other Geometrical way (either by infinite excursions or remotion of Centres) may prove either very difficult, or at least inconvenient; I have exemplified it only in Horizontal, Direct North or South Recliners, and in Vertical or Upright Declining Plains, as of all other the most General. The Order of the Four Parts, as they are now Printed, are as followeth, viz.

The first Part is Geometrical, and performeth the whole Doctrine of Dialling by Scale and Compasses; by Projecting of the Sphere in Plano upon the Dial Plain it self, i. e. By drawing upon the Plain such Circles of the Sphere in their true Position, as any way relate to the delineating of the Hour-lines upon such a Plain, let the Plain be in any position, and the Place in any situation, in respect of Latitude; by which manner

TO the READER.

of delineation, the Hour-lines, the place of the Substile, and Stile's height above the Plain, shall naturally fall in their due places upon the Plain, having no other consideration, than only knowing how the Circles of the Sphere are posited upon the Globe it self; which will be sufficient to carry you through the whole Work. And to that end (after some few necessary Geometrical Problems) at the beginning of the Book, I have inserted some Astronomical Elements also, giving the Reader a brief account of those Circles, and also of their situation upon the Globe: And in the Conclusion of this first Part I have (as my last Example of Declining Reclining Dials; which Plains of all others, are the most difficult to draw Hour-lines upon) so Projected the Sphere for that purpose, that not only the Making, but the Reason also of the delineation of that Dial (and consequently of any other) is demonstratively discovered.

The second Part is Arithmetical, shewing how by Arithmetical Calculation (by help of the Canons of Artificial Sines and Tangents) to find the situation of any Plain, and from thence to calculate the true places of the Stile, Substile, and Meridian, as also of the Hour distancer, and that upon all sorts of Plains, from the Horizontal or Vertical, to such as Decline or Recline, or both. And in this Part I have taken my Examples (for the most part) the same as in that fore-going, and that for these two Reasons principally. (I.) For the saving my self the labour of calculating of so many New ones. But (II.) and chiefly, for the Practitioner's satisfaction,

To the READER.

isfaction, that he may see what harmony there is between Arithmetical Calculation and Geometrical Projection.

The third Part is Instrumental, and teacheth how to delineate Hour-lines upon all sorts of Plains, by help of a Plain, Cheap, and Portable Instrument, which I call a HOROLOGICAL TRIGON, by which the Stile, Substile, and Hour-lines, upon any Plain, may easily and speedily be Protracted, having very few lines to draw, but the Requisites themselves, and in any case, seldom exceeding the Confines or Limits of the Plain it self. And with this Instrument and its Use I conclude this Treatise.

It may now be expected that I should shew how to beautifie or adorn those Dials, by inscribing upon them other Spherical Circles and Lines (besides the common hours) as the Equinoctial and Tropicks, the Parallels of Declination, Parallels of the Suns Place, of the Length of the Day, of the Suns Rising and Setting, the Jewish, Italian, and Babylonish hours, Almicanthera's Azimuths, Circles of Position, the Signs Ascending, Descending, and Culminating, and the like Spherical Conclusions: But in regard that (in part) some years since, I have (in an Appendix to a Book of Dialling) published a Geometrical way of performing many of these Conclusions upon some Plains, I was the more willing to omit them in this place at that time; my other occasions not giving me so much leisure, as to prosecute them things answerable to my own desire, or the ingenious Practitioner's satisfaction. But at that time,
I did

To the READER.

I did promise (God willing) that in due time I would publish something else of Dialling, and that not only of the making of Dials upon Plains, but upon irregular Superficies also, as upon Cylinders, Cones, and Spheres, both Concave and Convex, and also upon irregular Concave or Convex Superficies, and that both by Reflexion and Refraxon, with divers other things of the like nature: All which particulars, I have since that time performed, and the Book is now in the Press, an account of the Title whereof, and of the particulars therein contained, is given in a Postscript at the end of this Book.

And now, Reader, let me acquaint thee, That in the former Edition (in regard of my remotion from the Press, and the carelesness of the Printer, and gross ignorance of his Corrector, such ridiculous faults and absurdities passed the Press, that when I came to peruse the Book, I could hardly (my self) in many places (without due consideration) understand it. But I have purged it from those Errors and Absurdities with which it was then burthened, to my vexation, and the great Trouble of the Learner; and now, is far more perfect, and nothing in it deserving an Errata. I this second time recommend it to thee, wishing all good success in thy Endeavours. And so for this time, Farewel.

A
CONNEXTURE
 OF
GEOMETRICAL PROBLEMES,
 AND
 ASTRONOMICAL ELEMENTS.

PROBL. I.

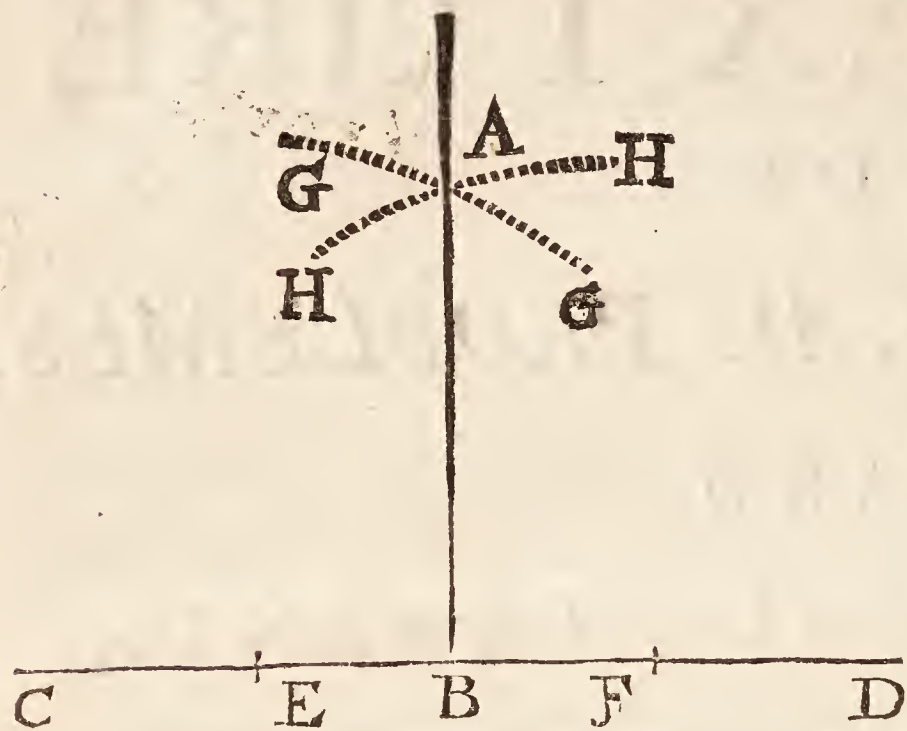
Upon a Right Line given, to erect a Perpendicular.

DEFINITION.

A Right Line is said to be Perpendicular to another Line, when it maketh the Angles on either side of the erected Line, equal, that is, so that the Line inclines not, either to the right or to the left, but standeth upright upon the Line, upon which it is erected, as in the following Figure, the Right Line A B is said to be perpendicular to the Line C D, upon which it is erected, because the Angles on either side thereof are equal; namely the Angle A B C on the one side, is equal to the Angle A B D, on the other side; and either of these Angles are called Right Angles, and the Line A B so erected, is called the *Perpendicular*.

PRACTICE.

Let CD be a Right Line given, and let it be required to erect a *Perpendicular* thereupon from the point B: Open your Compasses to any convenient small distance, and set-



ting one Foot in the point B, with the other, make the two marks E and F, on either side of the point B. ---This done, open the Compasses to any other convenient distance greater than the former, and setting one in the point E, with the other draw the obscure Arch G G, as

near as you may guess over the given point B. Again (the Compasses being still opened to the same distance) set one foot in the point F, and with the other Foot describe another obscure Arch H H, crossing the former in the point A, so is A the point through which, if you draw a right Line from the given point B, that Right Line A B, so drawn, shall be *Perpendicular* to the given Line C D, and from the point B, as was required.

PROBL. II.

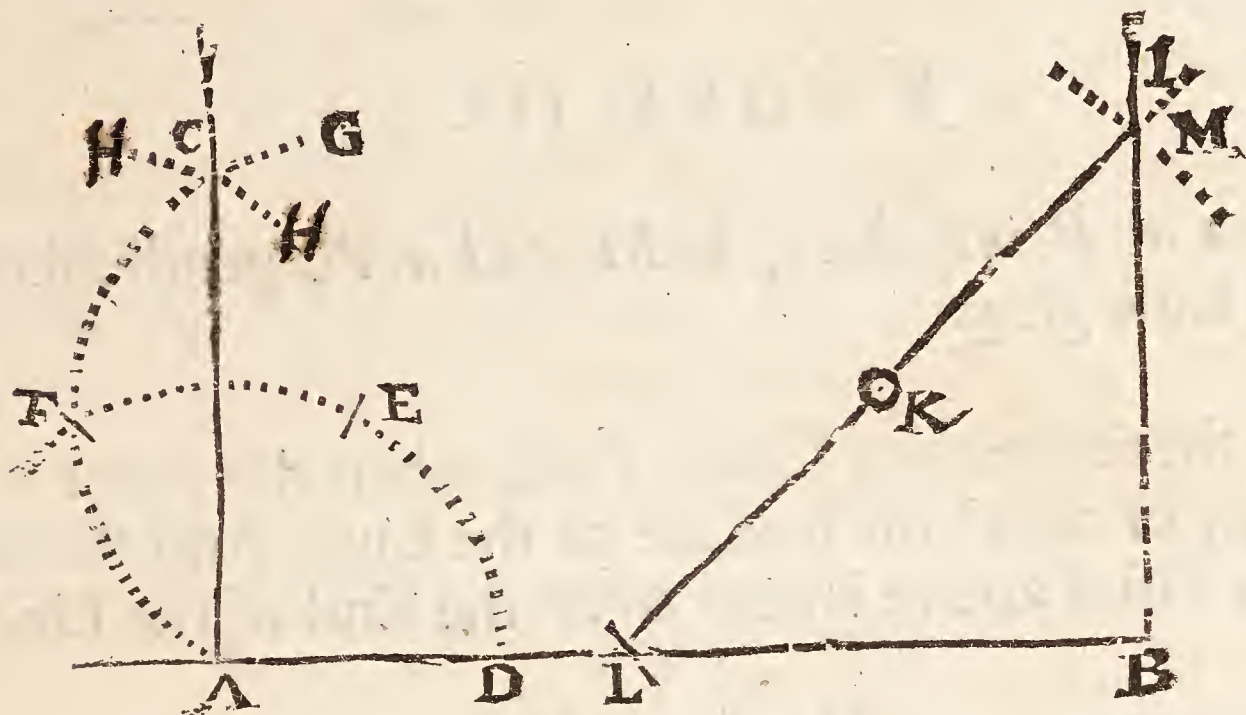
How upon (or near) the end of a given Right Line, to erect a Perpendicular.

TO effect this, there are several ways, but I will instance only in two, which are familiar and easie.

The

The First Way.

Let A B be a Line given, and from the point A, which is towards the end thereof, let it be required to erect a Per-



pendicular A C. —First, Open your Compasses to any small distance, and setting one foot in the given point A, with the other describe the Arch F E D, then set one foot of the Compasses in D, (they being opened to the same distance) cross the Arch in E, and setting one foot in E, with the other describe the Arch A F G crossing the first arch in F. Again, set one foot in F, and with the other describe the small arch H H, crossing the former in the point C: so the line A C being drawn, it shall be perpendicular to the given Line A B, and from the point A, as was required.

The Second Way.

Let B be the point given, and from it let it be required to draw the line B I, Perpendicular to A B. -----Open the Compasses to any small distance, and setting one foot in the given point B, pitch down the other foot at all adventures, as at K, so the one foot being in K, turn the other foot about
B. 2 till

till it cross the given line $A B$ in L , then draw the line $K L$, and set the same distance $K L$, (at which the Compasses already stand) from K to M , so a Line drawn from B , through M , shall be *Perpendicular* to $A B$, and from the given point B , as was required.

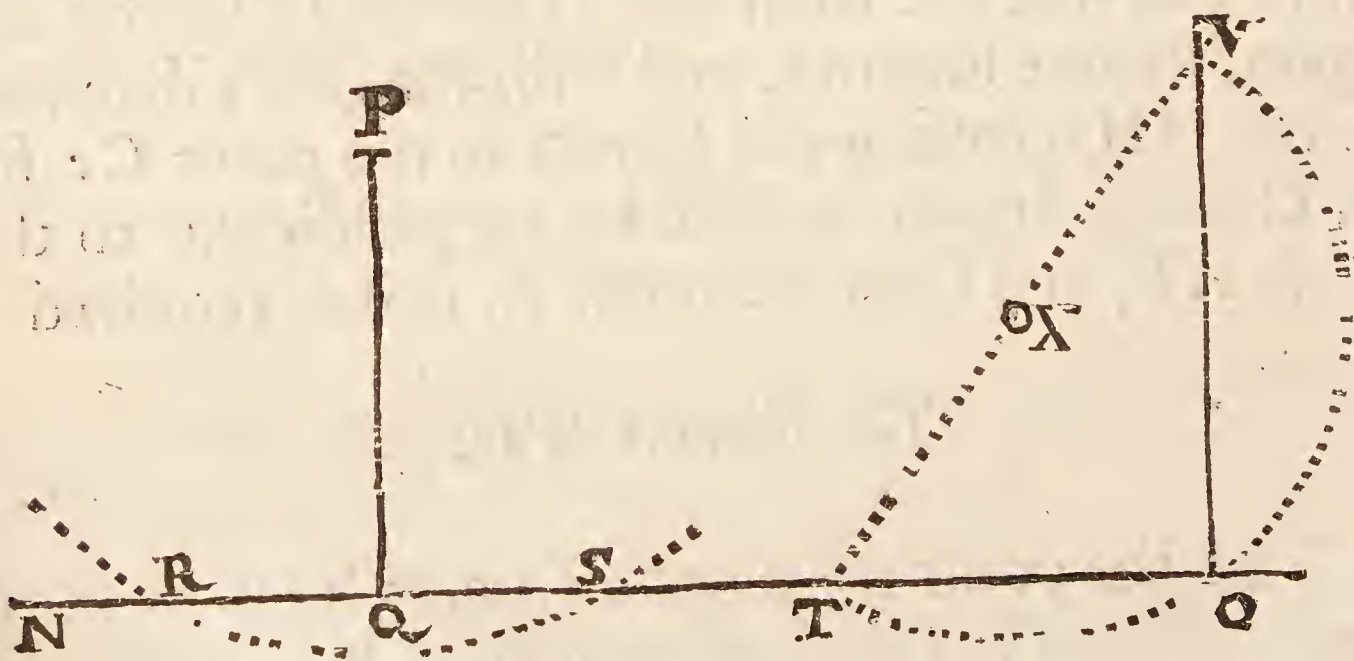
PROBL. III.

How from a Point above, to let fall a Perpendicular to a Right Line given.

IN this there are two Cases. First, when the point above is over (or near) the Middle of the Line. And Secondly, when the Point above is near over the End of the Line.

The First Case.

Let NO be a Right Line given, and from the point P , over it, let it be required to let fall the *Perpendicular* PQ .
---First open your Compasses to any distance greater than



P Q, and setting one foot in the given point P, with the other describe an Arch of a Circle, cutting the given line N O, in the points R and S. Then, Secondly, divide the space between

tween R and S in two equal parts in Q, (by the Fourth Probleme following) so a line drawn from the given point P, to Q, shall be *Perpendicular* to the given line N O.

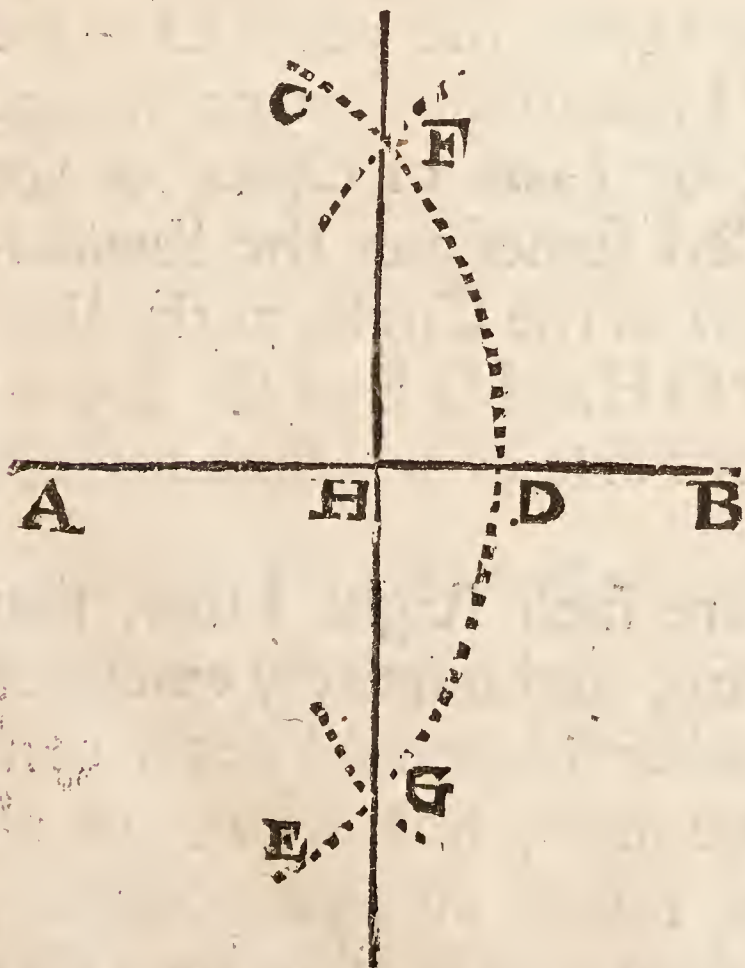
The Second Case.

Let V be the point given, from whence to let fall a Perpendicular to the line N O, ---First, from any part of the given line N O, as from T, draw a right Line to the given point V, which Line (by the next Problem) divide into two equal parts in the point X, with that distance of the Compasses (one foot being placed in X) with the other describe the Arch (or Semicircle) V O T, cutting the given line N O in O, so a Line drawn from V to O, shall be *Perpendicular* to the given line N O, and towards the end thereof, as was required.

P R O B L. IV.

How to divide a Right Line given, into Two Equal parts, and at Right Angles.

L Et the line A B be a line given, to be divided into two equal parts at Right Angles. Take in your Compasses the length of the line A B, or (if that be too long) any other distance above half the length thereof, and setting one foot in the end A, with the other draw the Arch C D E, (then the Compasses unaltered) set one foot in B, and with the other foot cross the former arch (both above and below the line) in the points F and G; then a line drawn from F to G, shall cut the given Line in H, so shall A B be divided in two Equal Parts in the Point H, and at *Right Angles*, which was required.

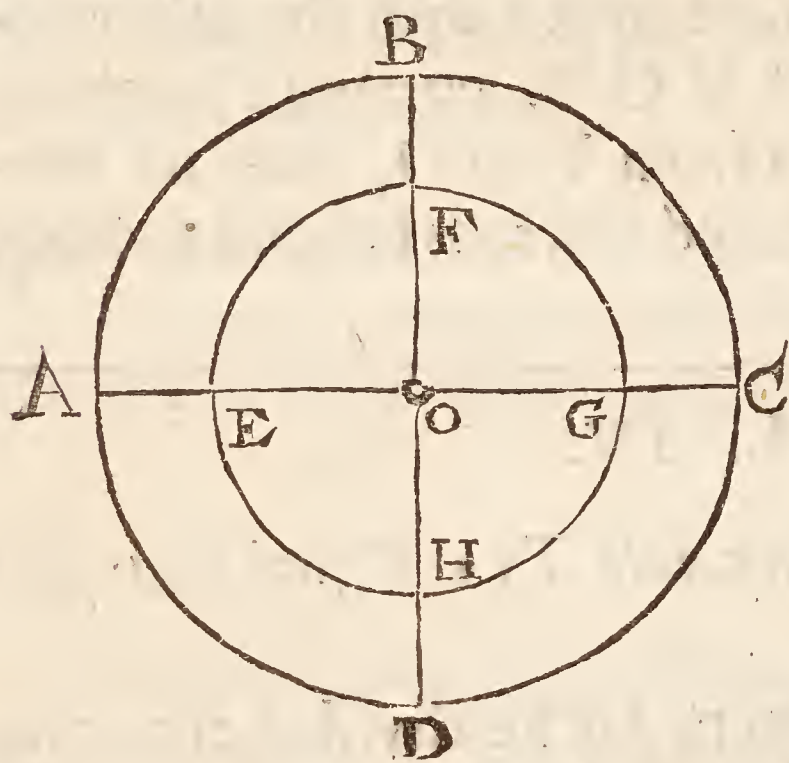


PROBL. V.

A Right Line being given, how to draw another Right Line, which shall be Parallel thereunto, at any distance required, or through any point assigned.

DEFINITION.

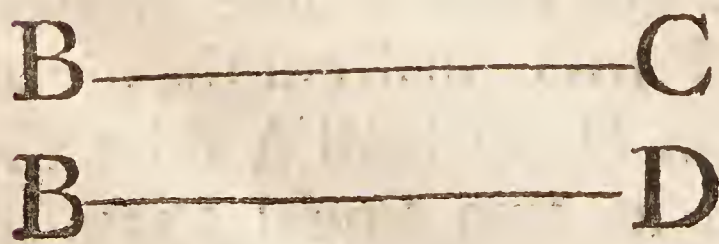
OF Parallel Lines, there are principally Two kinds, viz. Streight or Right Lined Parallels, and Circular Parallels. All Circles that are described or drawn upon the same



Centre, whether they be greater or lesser one than the other, are said to be *Parallel* or *Concentrick Circles*, as the Circle A B C D, may be said to be a *Concentrick Circle* with, or a *Parallel Circle* to E F G H, because both of them are described or drawn upon the same point or *Centre O*; and of both these *Circles*, the right line A C is the *Diameter* of the

Greater Circle, and E G of the Lesser, the point O is the *Centre* of both, and all Right Lines drawn from thence to the *Periphery*, *Circumference*, or *Limb* of either of the *Circles*, are Equal, and are called sometimes the *Semidiameters*, and sometimes the *Radius* of the Circle, as the lines O C or O B of the Greater, and O H and O E of the Lesser: It containing 60 such Degrees or Parts, of which the whole Circle contains 360.

But *Right Lined Parallels*, are such Right Lines, that being drawn upon the same Plain, and infinitely extended



on either side, would never concur or meet, but always in all parts, retain an equal distance, and such are the right lines B C, and B D, in the Margin.

In

In the describing or drawing of Parallel Lines, there may fall out Two Cases or Varieties: As,

1. It may be required to draw a *Right Line Parallel* to another *Right Line*, at a *Distance* given: Or,
2. It may be required to draw the *Parallel Line* through a *Point* assigned.

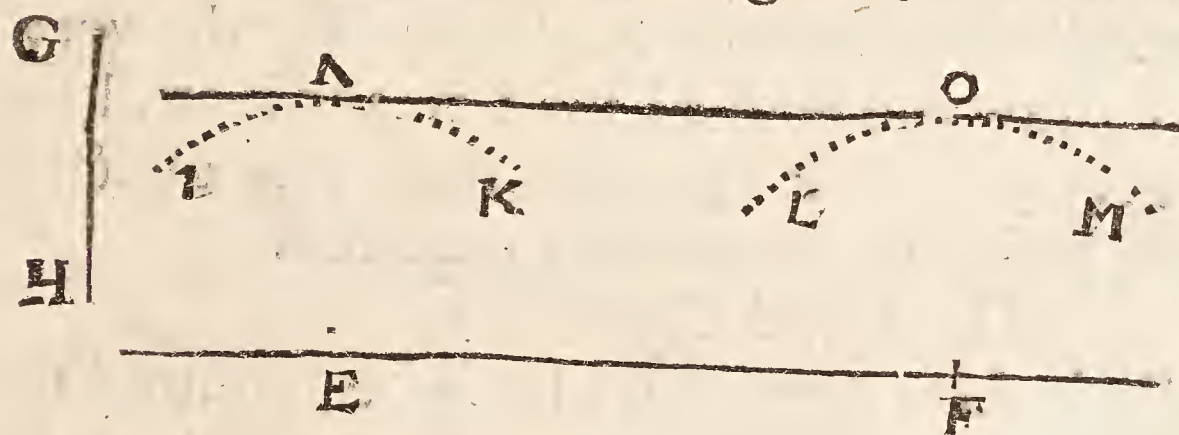
And of this kind there may be two Cases; For,

1. The given *Point* may be *Over* or *Under* the *Given Line*; Or,
2. It may be *Oblique* to the given *Line*.

P R A C T I C E.

Of the First Case.

Let *E F* be a *Right Line* given, and let it be required to

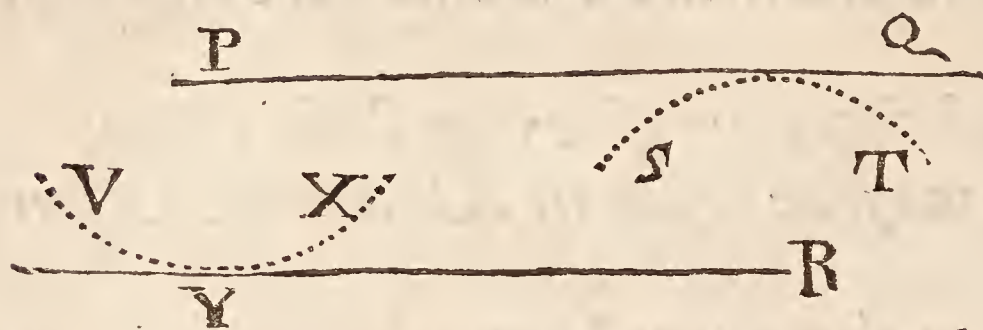


draw another *Right Line parallel* thereunto, at the *Distance* of the Points *G* and *H*.

Take in your *Compasses* the given distance *G H*, then setting one foot of the *Compasses* in *E*, (or any other point near the ends of the given *Line*) describe a small obscure Arch of a *Circle*, as *I K*. Then moving the *Compasses* to *F* (towards the other end of the given *Line*) describe another obscure Arch as *L M*; then lay a *Ruler* to the very top of these two Arches, so that the *Ruler* do not cross, but justly touch either of them: then by the side of the *Ruler* draw the *Line N O*, and it shall be *Parallel* to the given *Line E F*, and at the distance *G H*, which was required.

The Second Case.

Let PQ be a *Right Line* given, and let it be required to draw another *Right Line Parallel* thereunto, which shall pass through the point R .



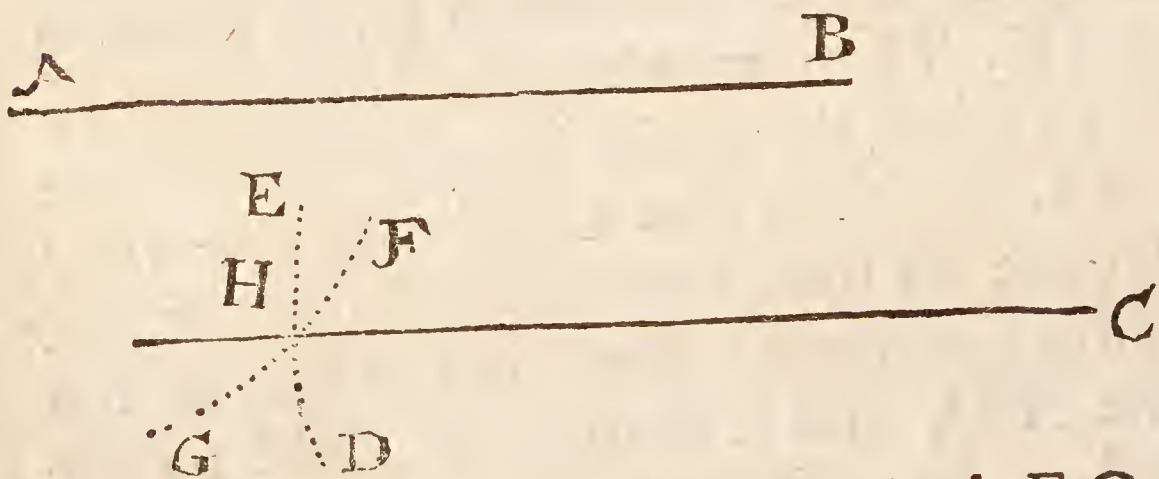
First, Set one foot of your Compasses in the given point R , and with the other take the nearest distance to

the given Line PQ , which is done by opening or shutting of the Compasses, till the moveable point do only touch the given line PQ , describing the Arch ST . The Compasses still resting at this distance, set one foot in P , (or any other points towards the end of the given Line) and with the other foot describe the Arch VX . Lastly, By the very top of this Arch Y , draw the *Right Line* YR , and it shall be *Parallel* to the given Line PQ , and shall pass directly through the given Point R , which was required.

The Third Case.

Let AB be a *Right Line* given, and let it be required to draw another *Right Line Parallel* thereunto, which shall pass through the *Point C*.

Take in your Compasses the distance from the given *Point C*, to the end of the given line B , then set one foot in A , the other end of the given line, and with



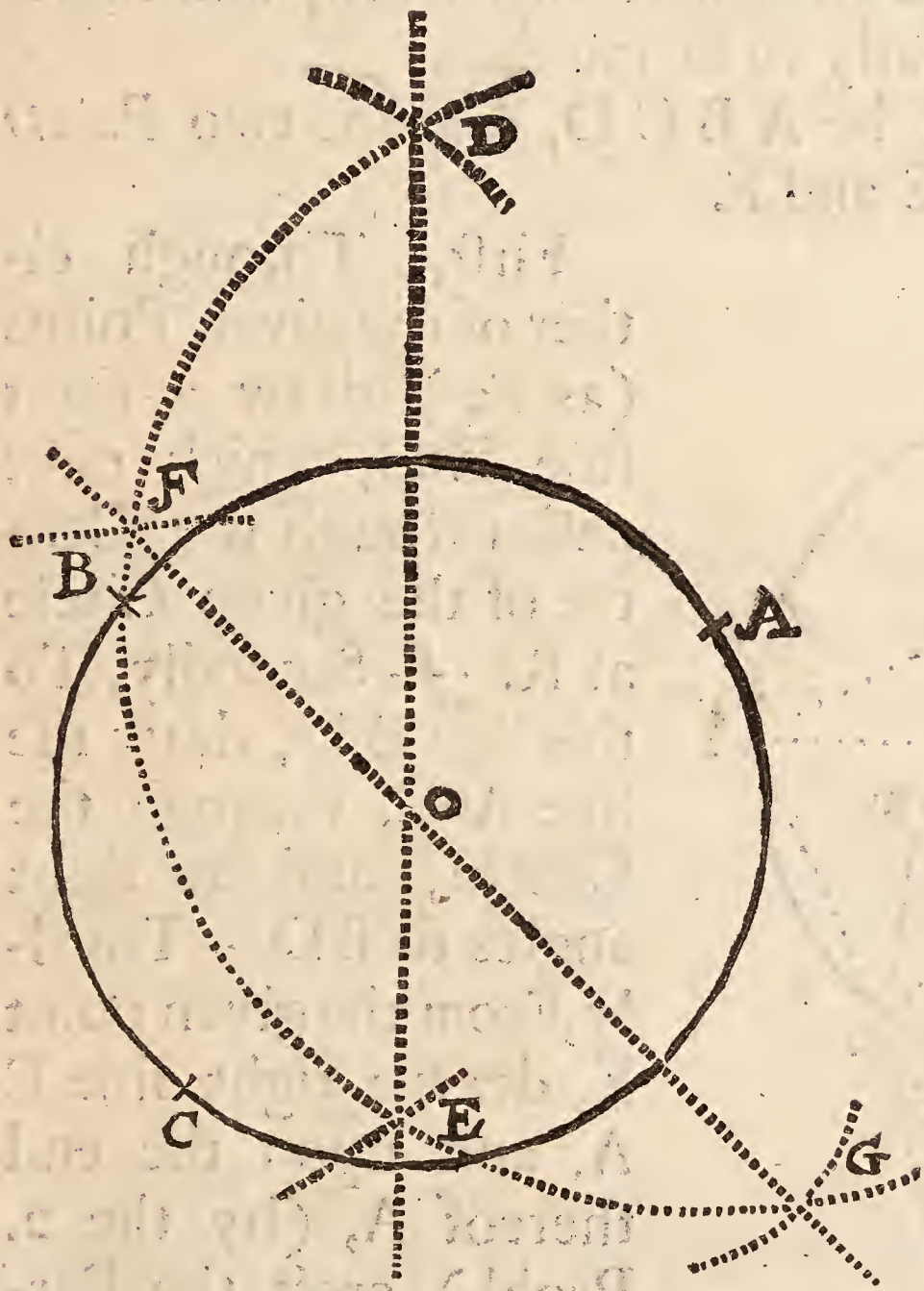
the other Foot describe the Arch FG . Again, Take in your Compasses the length of the given line AB , and setting one foot of that distance in C , with the other describe the arch DE , crossing the former arch in the point H , so the Line HC being drawn, shall be *Parallel* to the Line AB , and shall pass through the given point C , as was required.

PROBL.

PROBL. VI.

Any Three Points (which are not in a straight Line) being given; how to find the Centre of a Circle, which shall pass through those Three given Points.

L Et the three given points be A B and C, through which it is required a Circle should be described: First, Set one Foot of the Compasses in one of the given



points as in A, and extend the other foot to B, another of the Points, and draw the arch of a Circle G F D, ---- Secondly, the Compasses not altered, set one foot in B, and with the other, cross the former Arch with two small Arches, in the points D and E, and draw the Right Line D E. ---- Thirdly, set one foot of the Compasses in the third point C, (they still keeping the same distance) and with the other foot cross the

first drawn Arch, G F D, in the points F and G, and draw the Right Line F G, crossing the former right line D E, in the point O. So is O the Centre sought for; upon which, if you describe a Circle at the distance O A, it shall pass through all the three given Points A B and C, as was required.

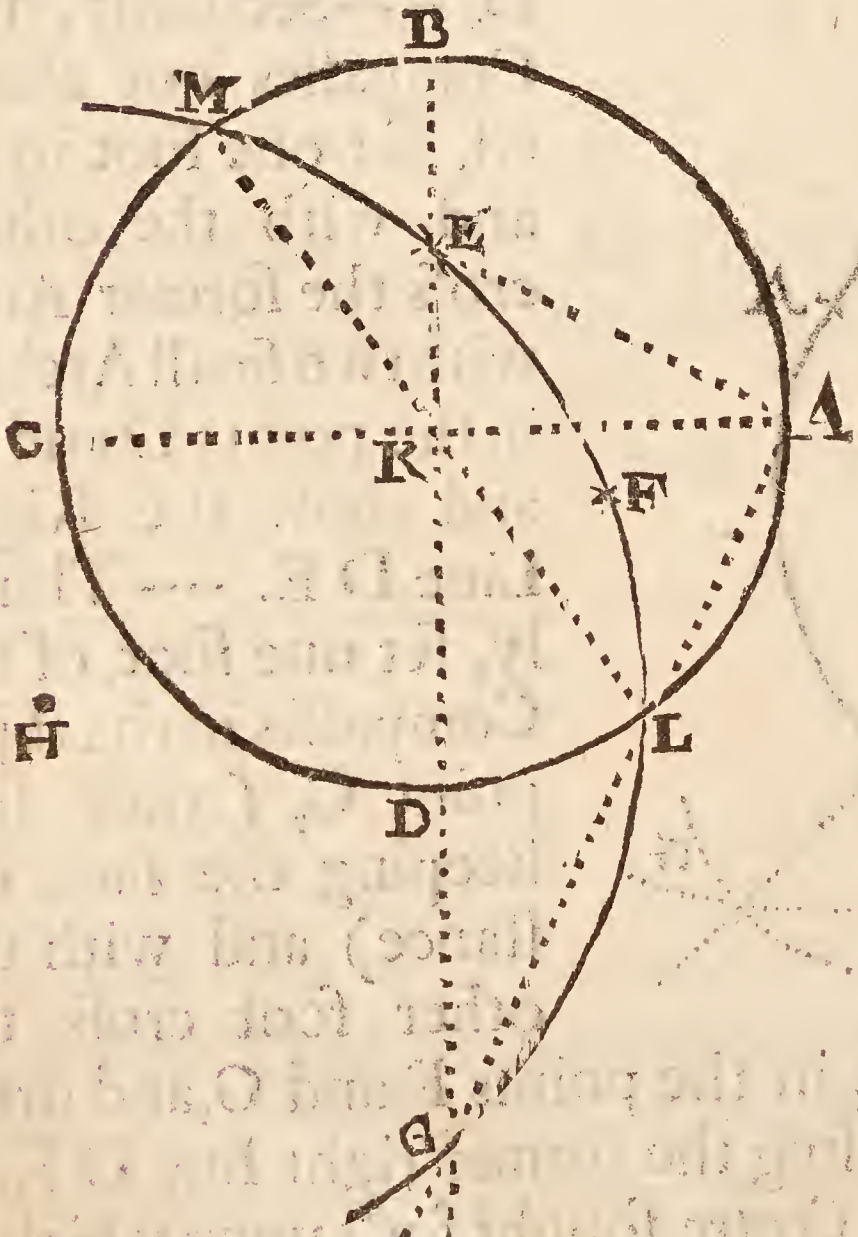
PROBL. VII.

Two Points within a Circle being given, how to find the Centre of a Circle, which being described, shall pass through the Two Given Points; and shall also divide the Periphery or Circumference of the given Circle into Two equal Parts.

THis and the foregoing Proposition, come in continual use and practice throughout this work, and therefore ought more especially to be minded.

Let the *Circle* given be A B C D, and the two *Points* within the same, be E and F.

First, Through either of the given Points (as E,) draw a right line E D, which must pass through the Centre of the given Circle at R. --- Secondly, To this line B D, draw the line A C, through the Centre, and at right angles to B D--- Thirdly, From the given point E, draw a right line E A, and upon the end thereof A, (by the 2. Probl.) erect the Perpendicular A G, crossing the Line B D, (it being extended) in the point G, so shall G be a third point, and then (by the last Problem) you



you may find a Centre, upon which a Circle being described, shall pass, whose Centre will be at H, without the given Circle, upon which point, if you describe the arch of a Circle at the extent or distance of H E, H F, or H G, it shall pass through the two given *Points* E and F, and shall also divide the given Circle *A B C D*, into two equal parts in the points M and L, which was required. And that this *Arch* thus drawn doth divide the given Circle into two equal parts is evident, for a Line drawn from L to M, will pass directly through the Centre of the given Circle, and shall therefore divide it into two equal parts.

PROB L. VIII.

How to make a Line of Chords Geometrically, to any assigned Length or Radius.

FOrasmuch as through this whole Treatise, there is continual mention and use made of a Line of *Chords*, it will not be impertinent in this place to discover the making thereof, for the convenience of such, as at all times, and in all places, cannot have the benefit of the Mathematical Instrument-maker, to whom these things are common.

DEFINITION.

A *Line of Chords* is no other than 60 Degrees of the Arch of any Circle, transferred from the Limb of a Circle to a Streight Line; now every Circle great or small, is divided (or supposed so to be) into 360 equal parts, called *Degrees*, so the Semicircle contains 180, the Quadrant 90, and the *Radius* or *Semidiameter* (which is that Line upon which the Circle or Semicircle is described) noted in the following Figure with the Letters A B, is always equal to 60 degrees of that Circle which it describes, and therefore

60 degrees of a *Line of Chords* is called the *Radius* thereof. Thus much for the *Definition* of a *Line of Chords*, now for

The CONCLUSION.

First, Draw a Right Line of any length, as C B D, and upon the middle thereof, (*by the First or Fourth Problem*) erect the Perpendicular A B.

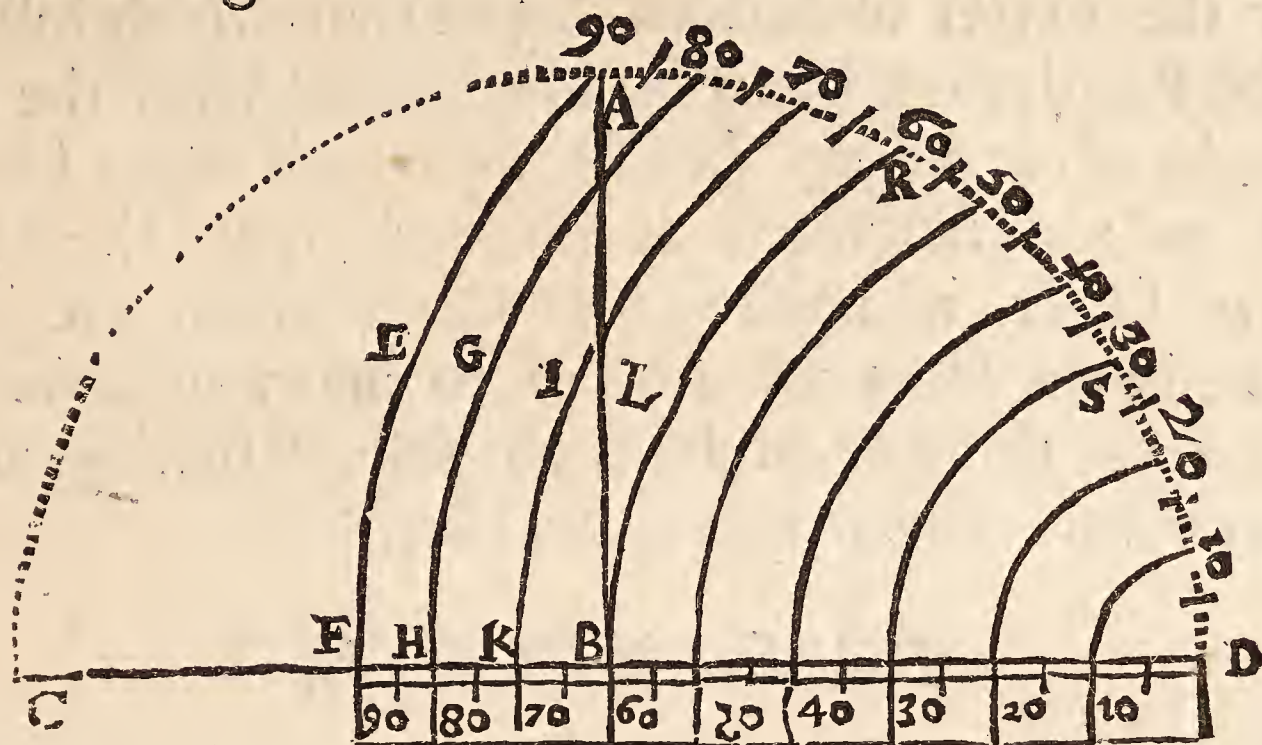
Secondly, Open your Compasses to the *Radius*, or length that you would have your *Line of Chords* to be of, which suppose A B, (*which I make here equal to the Line of Chords that most of the Schemes and Diagrams in this Book were described by*) and with that distance upon B, as a Centre, describe the Semicircle C A D, which is divided into two equal parts or Quadrants by the Perpendicular Line A B.

Thirdly, Divide the Arch or Quadrant A R D, into 90 equal parts or degrees, which you may do in this manner [Take the length of the Line A B, and set that distance upon the Quadrant A D, from D to R, so is D R 60 deg. and A R 30 deg. Then take the distance A R, and set it from D to S, so is the Quadrant divided into three equal parts, at the points S and R, each containing 30 deg. This done, divide the several spaces between A R, R S, and S D, into 3 equal parts, each of which will be 10 deg. according as you see the numbers set to them, these must be again divided into two equal parts, each part containing 5 degrees, and every of those into five smaller, as you see in the Figure, and so will the whole Quadrant be divided into 90.]

Fourthly, The Quadrant A R S D being thus divided into 90 parts or degrees, set one foot of your Compasses in D, and open the other foot to A, and describe the Arch A E F, touching the Line C D in F, so is the point F, upon the Right Line C D, the *Chord* of 90 deg.

Fifthly,

Fifthly, Open the Compasses from D to 80 deg. and describe the Arch 80 G H, so shall the point H be the *Chord* of 80 deg.



Sixthly, Open the Compasses from D to 70, and describe the Arch 70 I K, so is K the *Chord* of 70 deg.

Again, Open the Compasses from D to R, the Radius, or 60 deg. and describe the Arch R L B, so is B the *Chord* of 60 deg. equal to the Radius.

Do the like with 50, 40, 30, 20 and 10 deg. So shall you have the line D F divided into 90 ~~unequal~~ equal parts called *Chords*.

In this manner may you make a Line of Chords of any length, and set it upon a Ruler, and it is fit for to perform all the uses in this Book, and it were convenient that upon one and the same Ruler, you had three, four, or five *Chords* of several lengths or Radiuses, as in Practice you will find to be necessary and commodious.

Being thus provided of a Line of Chords, I will now shew you how to work two Conclusions Geometrically, which are of absolute use in Dialling, the one is to find the Hour of the Day, and the other is to find the Azimuth of the Sun at any time, and in any place. And with them I shall conclude these Geometrical Problemes, and Astro-

Astronomical Elements.

FOR the better understanding of that which followeth, the Reader ought to be acquainted with the *Principal Circles of the Sphere*. As also, with such other *Lines*, and *Points*, as are described and noted upon the *Material Sphere* or *Globe*, in imitation of those which are imagined to be in the *Heavens*. And of so many of these as are necessary for this our present purpose, I shall give you a brief account. Know therefore, that,

D E F I N I T I O N.

A *Sphere* or *Globe* is a Solid Body, containing only one Superficies, in whose middle there is a Point, from whence all right lines drawn to this Superficies are equal.

The *Principal Circles* of which a *Sphere* or *Globe* is composed, are in number *Ten*, whereof *Six* are *great*, and *Four* are *smaller Circles*.

A *Great Circle* is that which divideth the Body of the *Globe* into two equal Parts or Hemispheres. A *Small Circle* is that which divideth the *Globe* into two unequal parts.

The Six Great Circles are,

- | | | |
|----------------------------|---|-----------------------------|
| 1 The <i>Horizon</i> , | } | 4 The <i>Zodiack</i> , |
| 2 The <i>Meridian</i> , | | 5 } The <i>Two Colmes</i> . |
| 3 The <i>Æquinoctial</i> , | | 6 } |

The Lesser Circles are,

- | | | |
|-------------------------------------|---|---------------------------------|
| 1 The <i>Tropick of Cancer</i> , | } | 3 The <i>Artick Circle</i> . |
| 2 The <i>Tropick of Capricorn</i> , | | 4 The <i>Antartick Circle</i> . |

Of these in the Art of *Dialling* there is principally but Five to be taken notice of, *viz.* Three *Great Circles*, and two *smaller Circles*.

The

The Great Circles are,

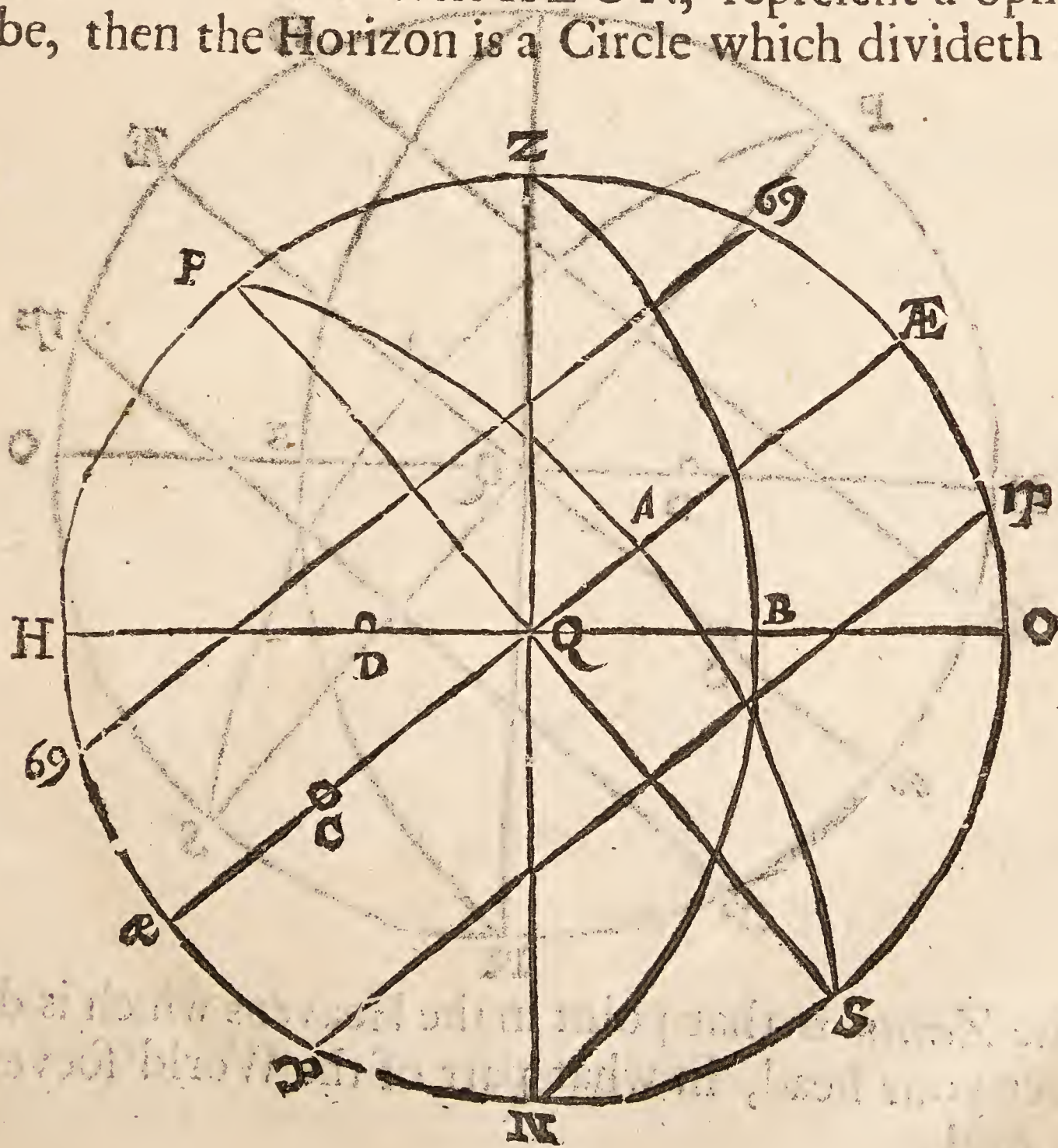
- 1 The *Horizon*,
- 2 The *Meridian*,
- 3 The *Æquinoctial*.

The Lesser Circles are,

- 1 The *Tropick of Cancer*,
- 2 The *Tropick of Capricorn*.

I. Of the HORIZON.

In the following Figure, let the outermost Circle thereof, noted with the Letters H Z O N, represent a Sphere or Globe, then the Horizon is a Circle which divideth or se-

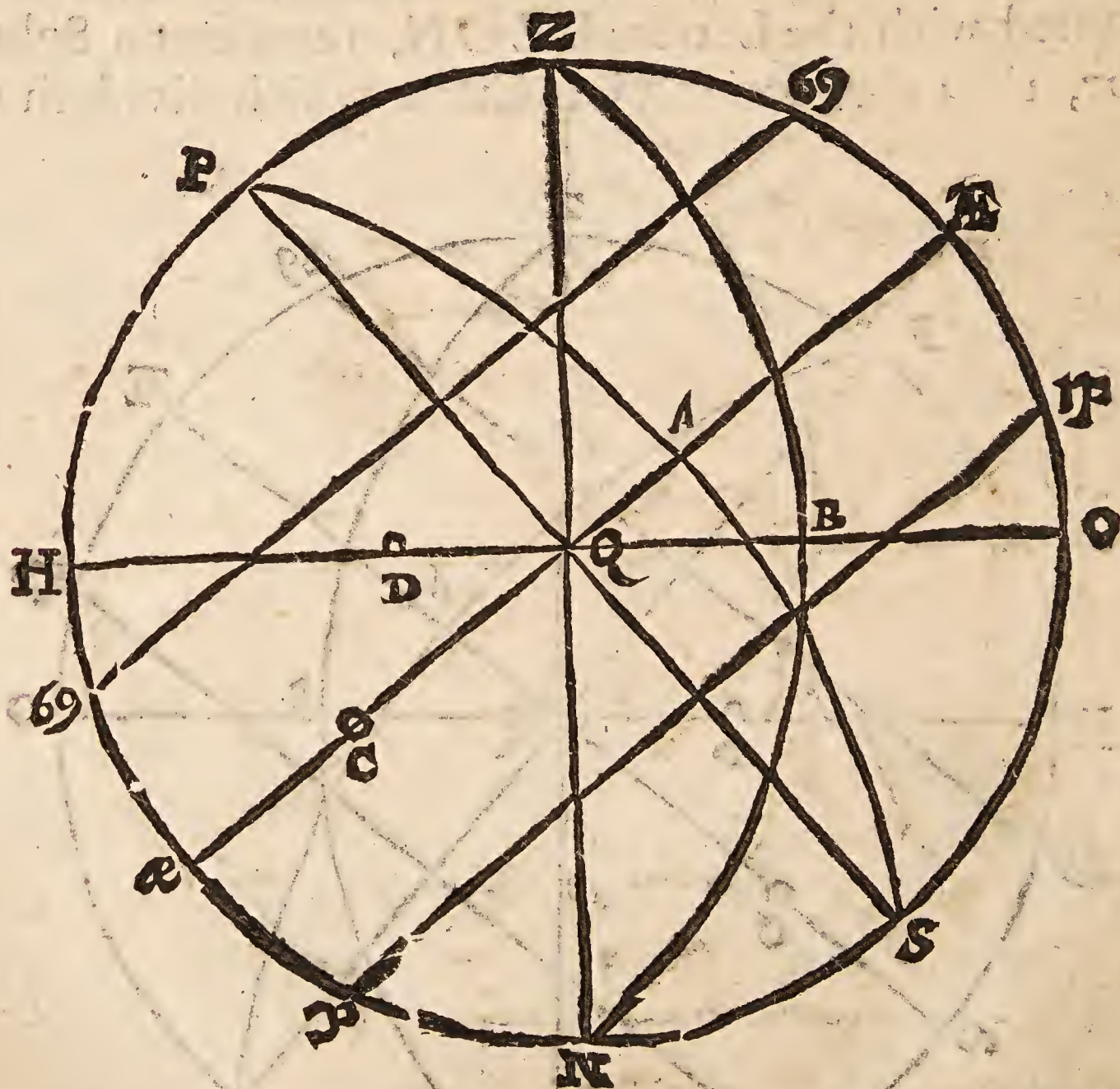


parateth

parateth the visible part of the Heavens which we see, from the invisible part which we see not, and is represented in the following Figure by the Line (which represents a great Circle) $H Q O$, separating the visible Hemisphere $H Z O$, which we see; from the invisible part thereof $H N O$, which we see not.

II. Of the Meridian.

The *Meridian* is a Great Circle of the Sphere which passeth by the *Poles* of the World, and through the *Zenith* and *Nadir* of the Place. To this Circle, when the Sun cometh, he being above our Horizon, maketh Noon or Mid-day, and being in the same Circle, when it is under the Horizon, it is then Midnight.



The *Zenith* is that point in the Heavens which is directly over your head, in what part of the World soever you be. And,

The *Nadir* is that point in the Heavens which is under your feet, directly opposite to the Zenith.

The Meridian Circle in this Figure, is noted with the Letters H Z O N, the point Z at the top representing the *Zenith*, and N the *Nadir* Points.

III. Of the *Æquinoctial*.

The *Æquinoctial* is a great Circle of the Sphere, dividing it into the Northern and Southern Hemispheres, which take their names from the two Poles, that being called the *Northern Hemisphere*, in which the *North Pole* is seated, and that the *Southern* in which the *South Pole* is seated. Unto this Circle when the Sun in his Annual motion arriveth) which is but twice in the whole Year) the Days and Nights are of equal length through the whole World.

This Circle cutteth the Axis of the World at Right Angles, and is seated in the Heavens 90 deg. or a Quarter of a Circle, distant from either of the Poles.

It is represented in this Figure by the Line or Circle Æ Q æ . The two Poles are noted with P and S; P being the *North*, and S the *South Pole*; and so the Hemisphere, æ P Æ , is the *Northern*, and Æ S æ the *Southern Hemisphere*. And the Right line P Q S, is the *Axis of the World*, crossing the *Æquinoctial* at Right Angles in Q, the Centre, or middle point of the Sphere or Globe.

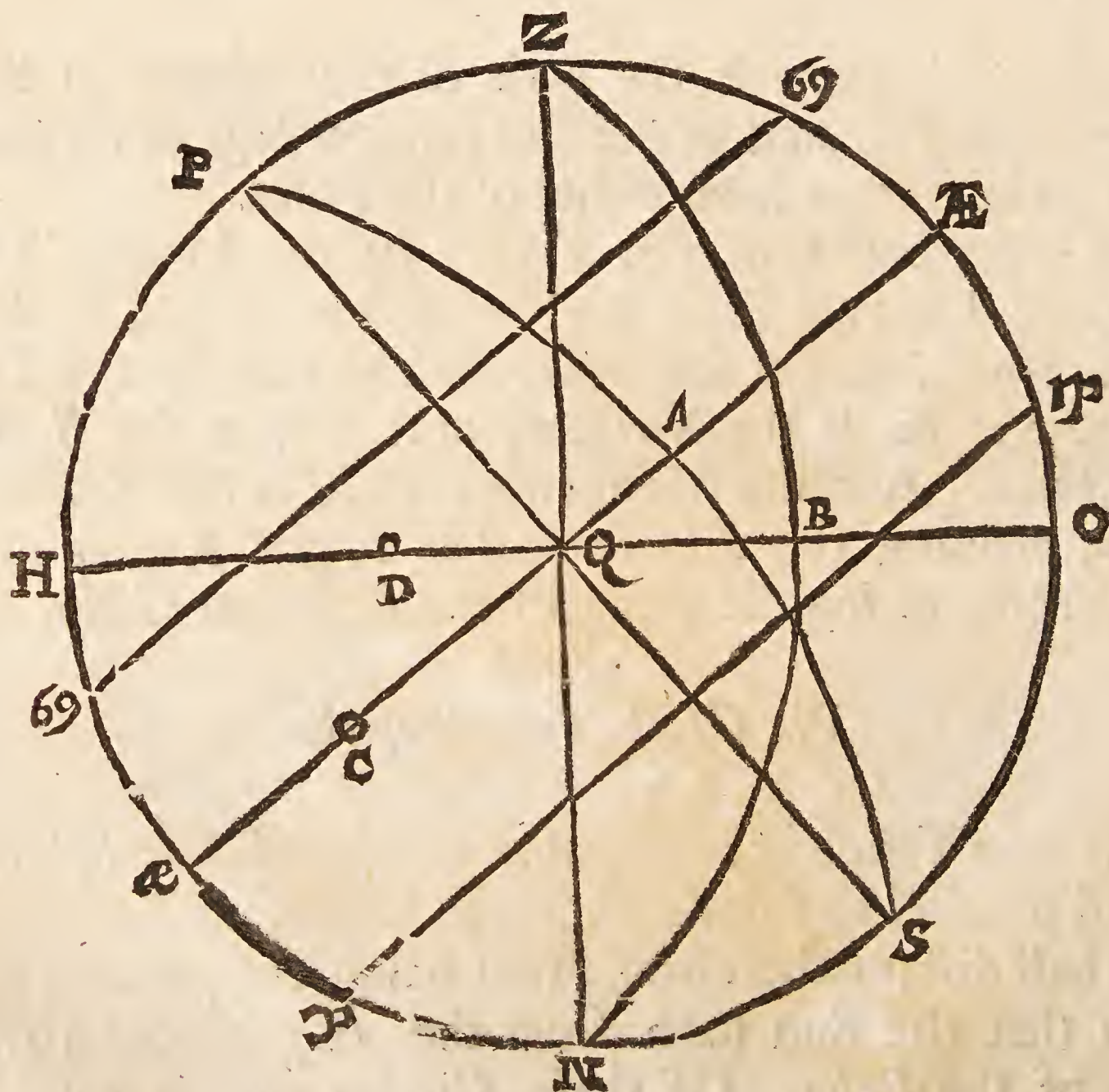
IV. Of the two Tropicks.

The two Tropicks are *Smaller Circles* of the Sphere described parallel to the *Æquinoctial* Circle, and at 23 deg. and a half distant therefrom; that being the greatest *Declination* that the Sun hath from the *Æquinoctial* towards either of the Poles. Of these Circles one is called the *Tropick of Cancer*, or Northern Tropick; the other the *Tropick*

D

pick of Capricorn, or Southern Tropick, so denominated, from the Poles which they respect or behold. As the Tropick of Cancer, marked with the character of *Cancer* ☊ ☊ at each end thereof, beholdeth P, the *North Pole*, and the Tropick of Capricorn, noted with the characters of *Capricorn*, ☋ ☋, at each end thereof respecteth S, the South Pole.

Thesetwo Circles are the bounds or limits of the Suns course, for between them he always moveth, never going more Northward or Southward, (that is, declines not nearer to any of the Poles) than 23 deg. 31 min. Wherefore, when the Sun in his annual course, shall arrive to the Tropick of *Cancer*, which is about the 10th. or 11th. of *June*, he maketh the *Longest Days* to all that inhabit in the Northern Hemisphere. And when he arriveth to the Tropick of *Capricorn*, which is about the 11th. of *December*, he ma-



keth the *Shortest Days* to those that inhabit the Northern, and the *Longest* to those of the Southern Hemisphere.

Besides

Besides these Circles here named, there are divers others described upon the Globe, Two sorts whereof, are of great use in Dialling, and therefore I shall make them known, viz.

Hour Circles, and Azimuths.

Hour Circles are great Circles of the Sphere, which meet together in the Poles of the World, and cross the *Æquinoctial* at Right Angles; of which the Meridian (or outward Circle in this Figure) is the hour Circle of 12, the streight line P Q S, which represents the Axis of the World, is also the Hour-circle of Six, and all the rest of the Hour-circles are drawn from Pole to Pole between them, as the Circle P A S represents the Hour-circle of 8 and 4 a Clock, and so of all the rest, which are 12 in number, representing the 24 hours of the day and night being taken round the Globe or Sphere.

Azimuths are also Great Circles of the Sphere, meeting together in the *Zenith* and *Nadir* points, and fall upon, or intersect the Horizon at right Angles; as the Hour-circles do the *Æquinoctial*. Of these Circles, the outermost Circle of this Figure represents the North and South Azimuth; and the line Z Q N the Azimuth of East and West, and is commonly called the *Prime Vertical Circle*. And all other circles drawn through the *Zenith* and *Nadir* points, and cutting the Horizon at right Angles, are intermediate Azimuths between the East and West, and the North or South Points. As in the Figure, the Circle Z B N is an intermediate Azimuth between the South and the West, it being 40 deg. distant from O the South point.

Every Circle of the Sphere hath its proper Poles, which are always 90 deg. distant from it in all parts.

So in the former Figure Z the *Zenith*, and N the *Nadir* points, are the Poles of the Horizon, they being 90 deg. distant

distant from O the South point, from Q the West point, and from H the North point of the Horizon.

Also Q is the Pole of the Meridian Circle H Z O N, it being 90 deg. distant therefrom in all parts.

Again P and S, the North and South Poles of the World, are also the Poles of the *Æquinoctial* Circle, they being removed therefrom on either side 90 deg.

But the Pole of the Hour-circle P A S is at C, and the Pole of the Azimuth Circle Z B N is at D, and how to find these Poles, and also the Poles of any oblique Circles, shall be discovered in divers places of the following discourse, where there is often occasion for the finding of them.

Note, And whereas throughout this Book there is continual mention made of Degrees and Minutes, know, that a Degree is the 360 part of any Circle, each of which degrees is supposed to be divided into 60 parts called Minutes, so that 45 min. is three quarters of a degree, 30 min. half a degree, and 15 min. one quarter of a degree, &c.

These are such *Astronomical Elements*, as I conceive, most necessary for the understanding of that which follows;

It resteth now that I shew how to perform two or three *Astronomical Conclusions* Geometrically, without which the knowledge of making of a Dial will be of little validity; for to what purpose will a Dial serve without it be rightly placed? Or how can you make a Dial for any appointed place, without you first know the position or situation thereof? And to these purposes are the following Conclusions subservient.

*And because it is requisite to know at all times of the Year, What declination the Sun hath from the *Æquinoctial* either Northward or Southward, I have therefore at the end of this Introduction, inserted two Tables, the one shewing the Suns Declination every day in the year. And the other a Table shewing the Latitudes of all the Principal Cities and Towns in England, Scotland and Ireland.*

PROBL.

PROBL. IX.

Having the Latitude of the Place, the Altitude of the Sun, and the Day of the Month given, to find the Hour of the Day, and Azimuth of the Sun.

L Et the Place be *London*, whose Latitude is 51 deg. 32 min. ---- Let the Suns *Altitude* be 45 deg. ---- And let the Day of the Month be the 11th. of *May*, at which time, by the following *Table*, the Suns *Declination* is 20 deg. 20 min. North.

First, Describe the Circle $H Z O N$, representing the Meridian of the Place; ---- Cross it at right Angles with the two Diameters $H Q O$, for the Horizon, and $Z Q N$ for the *Prime Vertical Circle*, or *Azimuth* of East and West.

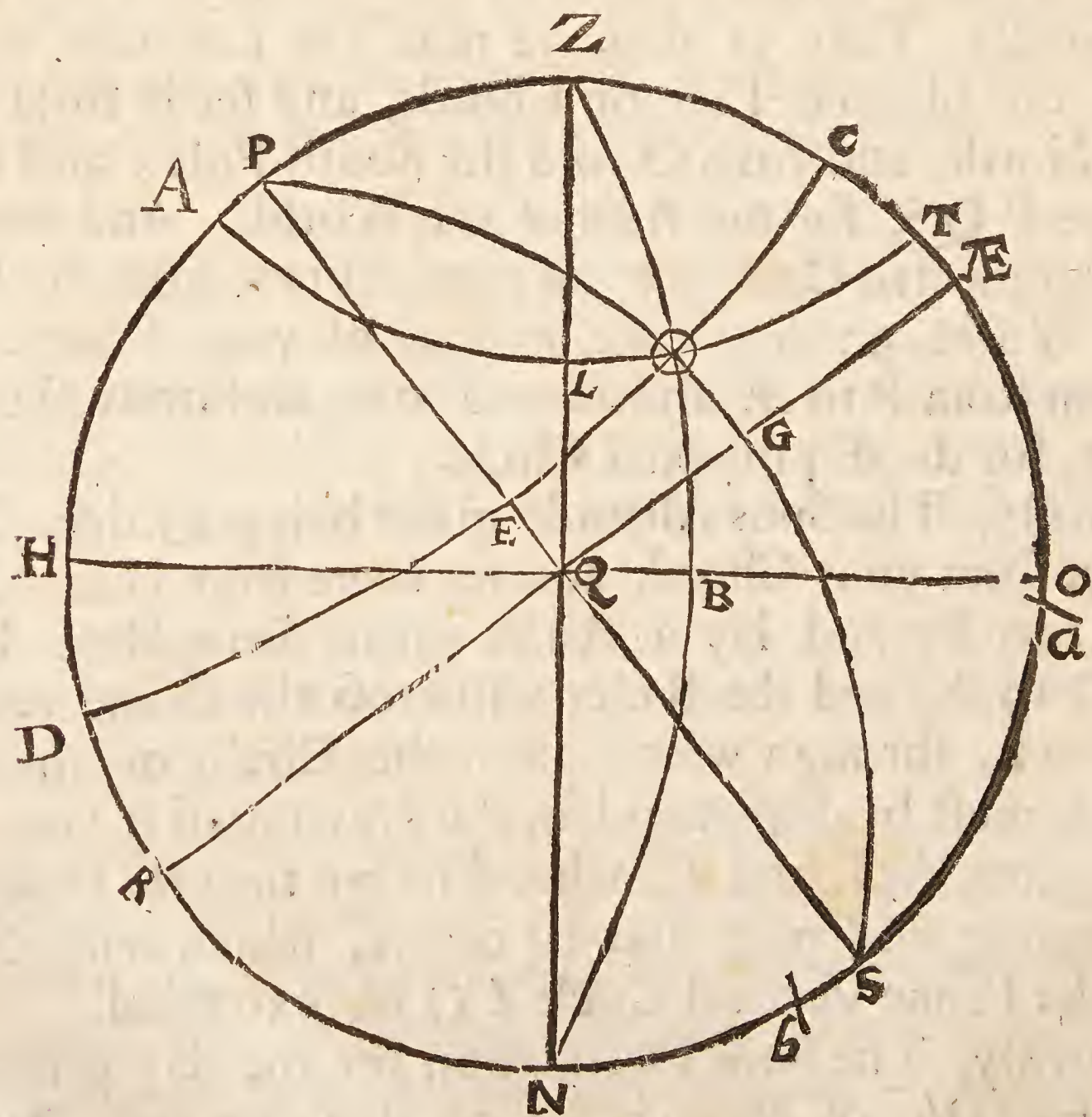
Secondly, Take 51 deg. 32 min. the Latitude of the Place, out of your Line of Chords, and set it from H to P the North, and from O to S the South Pole; and draw the line $P Q S$, for the Axis of the World. And because the *Æquinoctial Circle* is, in all parts, distant from the Poles of the World, 90 deg. take 90 deg. of your Chord, and set them from P to $Æ$, and from S to $æ$, and draw the line $Æ Q æ$, for the *Æquinoctial Circle*.

Thirdly, The Suns Altitude given being 45 deg. Take 45 deg. from your Chord, and set them from H to A , and from O to T ; and lay a Ruler either from H to T , or from O to A , and the Ruler will cross the Prime vertical Circle in L , through which point the Circle of the Suns Altitude must be drawn, and for the drawing of it, you have three points, A , L and T , wherefore by the 6th. Probleme beforegoing you may find its centre, which will always be in the Prime Vertical Circle $Z Q N$, extended.

Fourthly, The Suns Declination for the day proposed, *viz.* the 11th. of *May*) being 20 deg. 20 min. Northward, therefore take 20 deg. 20 min. out of your line of Chords.

Chords, and set them from Æ to C , and from æ to D , towards P the North Pole, because the Declination was North, otherwise it should have been set towards S the South Pole. ---- Then laying a Ruler either from Æ to D , or from æ to C , it will in both cases cut the Axis of the World in E , through which point the Parallel of the Suns declination for that day must be described, and for the drawing of it, you have three Points D , E and C , whose Centre will always be in the Axis of the World S Q P extended, and may be found by the former Sixth Probleme.

Fifthly, Observe in your Scheme, where the Parallel of Altitude A L T , and the Parallel of Declination D E C , do cross each other. which will be at the point \odot , and that is the place of the Sun at the time of the Question.



Sixthly, By the forementioned 6th. Probl. draw an Hour-circle

circle through the three points P \odot and S, whose centre will always be in the *Æquinoctial* line extended, if need be; also, through the Points Z \odot and N, draw an *Azimuth Circle*, whose centre will always be in the *Horizon* extended when need requires.

These two Circles being thus drawn, your Scheme is prepared for the finding both of the *Hour* and *Azimuth* in this manner.

I. For the HOUR.

Lay a Ruler to P, the Pole of the World, and G the point where the Hour-circle crosseth the *Æquinoctial*, and the Ruler will cut the Circle in *a*. So the distance from *a* to *Æ* being measured upon the line of Chords, will be found to contain 41 deg. 48 min. which is the *Hour* of the day, counted from Noon, which reduced into Time (by allowing 15 deg. to an hour, and 4 deg. to one minute of time) will be two hours, 47 minutes, that is, either 47 minutes after 2 in the After-noon, or 13 minutes after 9 in the Fore-noon.

II. For the AZIMUTH.

Lay a Ruler to Z the Zenith, and to B the point where the *Azimuth Circle* crosseth the *Horizon*, and the Ruler will cut the *Meridian Circle* in the point *b*, so the distance *b* O, being measured upon the Line of Chords, will be found to contain 62 deg. 8 minutes. And such is the Sun's *Azimuth* from the *South* part of the *Meridian*. ---- Or the distance N *b*, being measured upon the Chords, will be found to contain 27 deg. 52 min. which is the Sun's distance or *Azimuth*, from either *East* or *West*, according to the time of the day.

Thus by one and the same Projection of the Sphere, you have found both the *Hour* and the *Azimuth*, and many

Thirdly, Set 20 deg. the Suns Declination, from Æ towards Z , to the Point D , (being it is North) and draw the Line D T parallel to Æ Q , so is D B T the *Parallel of the Suns Declination*.

Fourthly, Set 12 deg. the Suns Altitude given, from O to L , and from H to M , and draw the Line M L , for the *Parallel of Altitude*.

Fifthly, Take in your Compasses, half the length of the Parallel of Altitude S L , or S M , and with that distance upon Q , describe the innermost Semicircle A C G .

Sixthly, From the point B , which is where the Parallel of Declination, and the Parallel of Altitude do intersect, erect the Perpendicular B C , till it touch the innermost Semicircle.

Lastly, Lay a Ruler from Q to C , and it will cut the outermost Circle in E , so shall H E measured upon the Line of Chords, be 72 deg. 52 min. the Suns Azimuth from the North part of the Meridian.

E Z shall be 17 deg. 8 min. the Azimuth from East or West. And,

E O shall be 107 deg. 8 min. the Azimuth from the South part of the Meridian.

Having made this fair Preparative, I will here insert the two fore-mentioned necessary Tables of the Suns Declination, and Latitudes of Places ; and then proceed to the Art of Dialling, the thing chiefly in this place intended.

A Table of the Suns Declination.

days.	January		Februar.		March		April		May		June	
	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.
1	21	44	3	46	3	24	8	36	18	5	23	12
2	21	33	13	26	3	0	8	58	18	20	23	16
3	21	23	13	5	2	37	9	20	18	35	23	19
4	21	13	12	45	2	13	9	42	18	50	23	22
5	21	2	12	25	1	49	10	3	19	4	23	25
6	20	50	12	4	1	25	10	24	19	18	23	27
7	20	38	11	43	1	1	10	45	19	31	23	29
8	20	26	11	21	0	38	11	0	19	44	23	30
9	20	13	11	0	0	14	11	27	19	57	23	31
10	20	0	10	38	0	10	11	47	20	10	23	32
11	19	46	10	16	0	33	12	7	20	22	23	31
12	19	32	9	54	0	57	12	28	20	34	23	31
13	19	18	9	32	1	21	12	48	20	45	23	30
14	19	3	9	10	1	44	13	7	20	56	23	29
15	18	48	8	48	2	8	13	27	21	7	23	28
16	18	33	8	25	2	31	13	46	21	17	23	26
17	18	17	8	3	2	54	14	5	21	27	23	23
18	18	2	7	40	3	18	14	24	21	37	23	20
19	17	45	7	17	3	41	14	42	21	46	23	17
20	17	28	6	54	4	5	15	1	21	55	23	14
21	17	11	6	31	4	28	15	19	22	4	23	10
22	16	54	6	8	4	51	15	37	22	12	23	6
23	16	36	5	45	5	14	15	54	22	20	23	1
24	16	18	5	21	5	37	16	12	22	27	22	55
25	16	0	4	58	6	0	16	29	22	34	22	50
26	15	42	4	34	6	22	16	46	22	41	22	44
27	15	23	4	11	6	45	17	2	22	47	22	37
28	15	4	3	47	7	7	17	18	22	53	22	31
29	14	45			7	30	17	34	22	58	22	23
30	14	26			7	52	17	50	23	3	22	16
31	14	6			8	14			23	8		

A Table of the Suns Declination.

Days	July d. mi.	August d. mi.	Sept. d. mi.	Octob. d. mi.	Novem d. mi.	Decem. d. mi.
1	22 8	15 12	4 24	7 15	17 40	23 9
2	22 0	14 54	4 2	7 38	17 56	23 13
3	21 51	14 36	3 38	8 0	18 12	23 17
4	21 42	14 17	3 15	8 22	18 28	23 20
5	21 32	13 58	2 52	8 45	18 43	23 23
6	21 22	13 39	2 29	9 7	18 58	23 26
7	21 12	13 20	2 5	9 29	19 13	23 28
8	21 2	13 1	1 42	9 51	19 27	23 30
9	20 51	12 41	1 19	10 13	19 41	23 31
10	20 40	12 21	0 55	10 35	19 55	23 31
11	20 28	12 1	0 32	10 56	20 8	23 31
12	20 16	11 41	0 8	11 18	20 21	23 31
13	20 4	11 21	0 16	11 39	20 34	23 29
14	19 51	11 0	0 39	12 0	20 46	23 27
15	19 38	10 39	1 3	12 21	20 58	23 25
16	19 25	10 18	1 26	12 41	21 9	23 22
17	19 12	9 57	1 50	13 2	21 20	23 19
18	18 58	9 36	2 13	13 22	21 31	23 16
19	18 43	9 15	2 37	13 42	21 41	23 12
20	18 29	8 53	3 0	14 2	21 50	23 7
21	18 14	8 31	3 25	14 21	22 0	23 2
22	17 59	8 9	3 47	14 41	22 9	23 57
23	17 44	7 47	4 10	15 0	22 17	22 51
24	17 28	7 25	4 33	15 19	22 15	22 44
25	17 12	7 3	4 57	15 37	22 33	22 37
26	16 56	6 41	5 20	15 55	22 40	22 30
27	16 39	6 18	5 43	16 1	22 46	22 22
28	16 22	5 56	6 6	16 3	22 52	22 14
29	16 6	5 33	6 29	16 49	22 58	22 5
30	15 48	5 10	6 52	17 6	23 4	22 56
31	15 30	4 47		17 28		21

*A TABLE of the Names and Latitudes
of the Principal Cities, Towns and Islands
in and about Great Brittain and Ireland.*

<i>England.</i>	D.	M.	<i>England.</i>	D.	M.
B Edford	52	8	Reading	51	28
Barwick	55	54	Salisbury	51	4
Bristol	51	27	Shrewsbury	52	47
Buckingham	52	0	Stafford	52	52
Cambridge	52	12	Stamford	52	38
Canterbury	51	17	Truero	50	30
Carlisle	55	0	Warwick	52	20
Chichester	50	48	Winchester	51	3
Chester	53	16	Worcester	52	14
Colchester	51	58	York.	53	58
Derby	52	58			
Dorchester	50	40			
Durham	54	50			
Excester	50	43			
Gilford	51	12			
Gloucester	51	53			
Hartford	51	49			
Hereford	52	7			
Huntington	52	19			
Ipswich	52	8			
Kendal	54	23			
Lancaster	54	10			
Leicester	52	40			
Lincoln	53	14			
London	51	32			
Northampton	52	14			
Norwich	52	41			
Nottingham	53	0			
Oxford	51	46			

<i>Wales.</i>	D.	M.
A nglesey	23	28
Barmonth	52	50
Brecknock	52	1
Cardigan	52	12
Carmarthen	51	56
Carnarvan	53	16
Denbigh	53	13
Flint	53	17
Landaff	51	35
Monmouth	51	51
Montgomery	51	56
Pembroke	51	46
Radnor	52	19
St. David.	52	0

Islands

<i>Islands.</i>	D.	M.	<i>Ireland.</i>	D.	M.
G Arnsey	49	30	A Ntrim	54	38
G Jersey	49	12	A Arglas	54	10
Limdy	51	22	Armah	54	14
Man	54	24	Caterlagh	52	41
Portland	50	30	Clare	52	34
Wight	50	39	Corke	51	53
			Droghedagh	53	38
			Dublin	53	20
<i>Scotland.</i>	D.	M.	Dundalke	53	52
A Berdean	57	32	Galloway	53	2
A Dunblain	56	21	Youhall	51	53
Dunkel	56	48	Kenny	52	27
Edenburgh	55	56	Kildare	53	0
Glasgow	55	52	Kings Town	53	8
Kinfaile	57	44	Knockfergus	54	37
Orkney	60	6	Kynsale	51	41
St. Andrews	56	39	Lymerick	52	30
Skyraffin	58	36	Queens Town	52	52
Sterling.	56	12	Waterford	52	9
			Wexford	52	18

The End of the Introduction.

The

The A R T of
D I A L L I N G

Geometrically performed,
 By Projecting of the Circles of the *Sphere*
 upon the *Plain* it self.

The First Part.

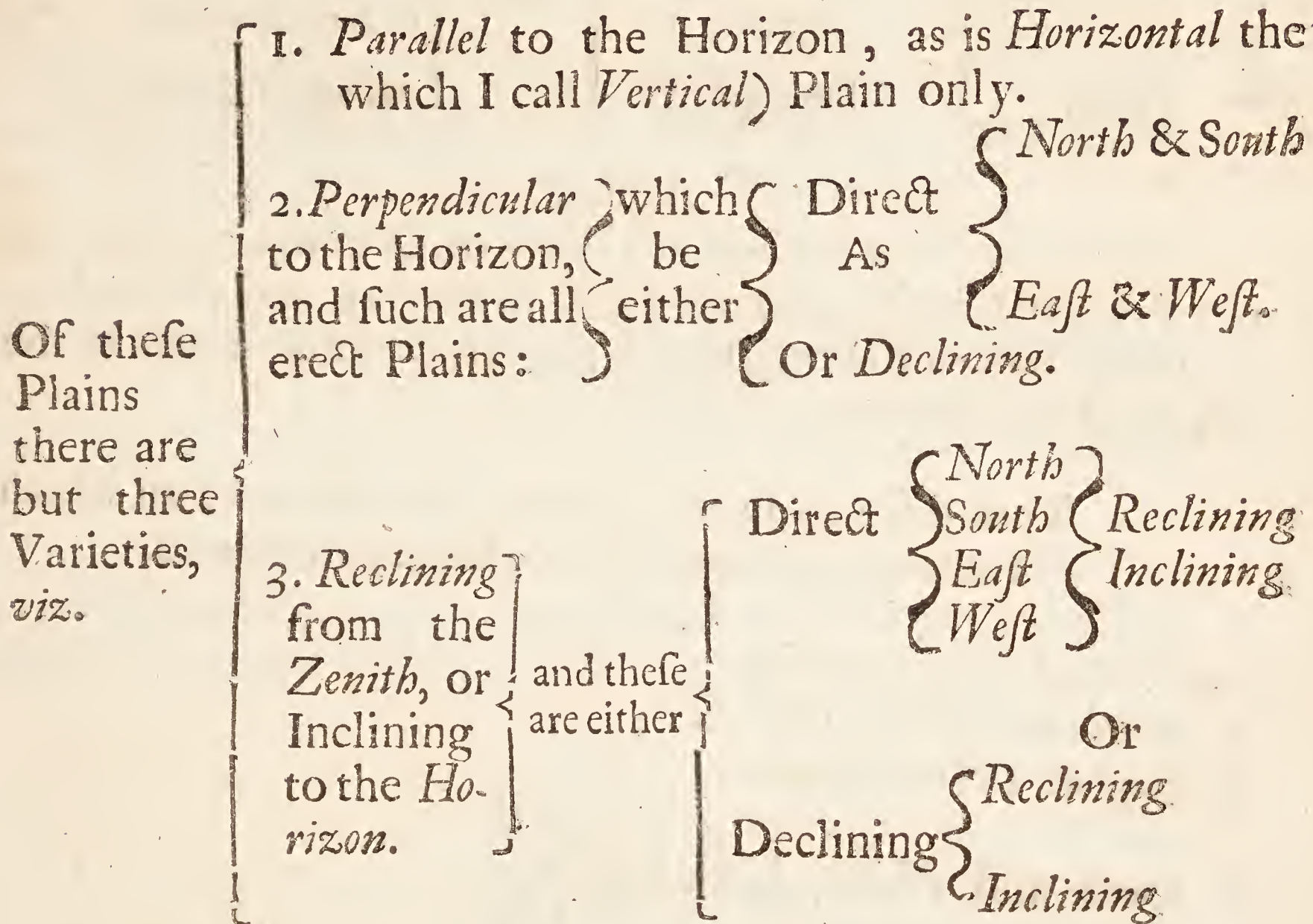
C H A P. I.

Of the several sorts of Plains upon which D I A L S are usually made.

D I A L S may be made upon any plain Superficies, and all plain Superficies are posited in one or other of these three positions, *viz.* either *Parallel, Perpendicular, or Oblique* to the *Horizon* of the Place wherein the Plain is seated, and all the Hour-lines drawn upon any Plain, are great Circles of the Sphere, which being projected upon a plain Superficies, become strait Lines.

Now

Now the Art of Dialling consisteth chiefly in the finding out of these Lines, and their true distances each from other, the which do continually vary, according as the Plains upon which they are described or projected, are scituated in respect of the *Horizon* of the place.



Now in the making of particular *Dials*, which are in number 25, I reduce them to 17, by supplying the *Inclining Plains* from their opposite *Recliners*, as being indeed the same.

And to avoid mistakes, which may possibly arise by comparing my *Examples* with other *Authors*, or others with mine, You are to take notice, that I denominate all my *Plains* from the sight (or the *Positions*) of their *Axis* in the *Heavens*, and not from the *Circles* of the *Sphere* in which they lie. Therefore take notice, That

Those

Those Plains which most Writers call	{	Horizontall	I call	{	Because their Poles do lie in the	{	Vertex or Zenith Point
		Vertical					North } Points of the <i>Horizon</i>
		Meridian					South } Points of the <i>Horizon</i>
		Equinoctial					East } Points of the <i>Horizon</i>
		Polar.					West } Poles of the World.
							Equinoctial Circle.

Again,

All leaning Plains whether Direct or Declining, whose upper Faces behold the *Zenith*, I call *Recliners*; and the nether, or under Faces of them, which respect, or look down to the *Nadir*, I call *Incliners*.

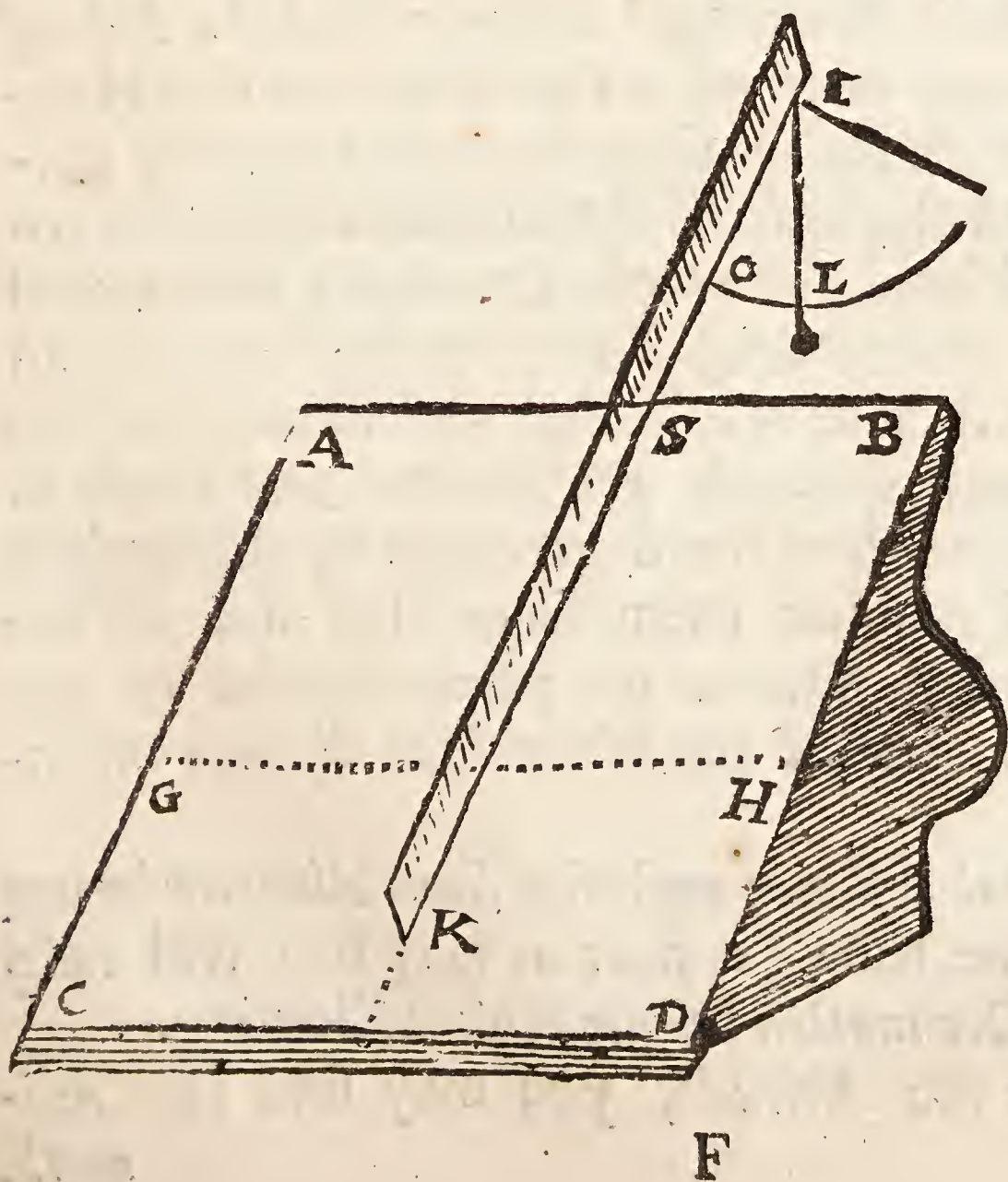
This distinction being made, the Plains of all which Examples following are thus denominated.

1. *Vertical* or *Horizontal*.
2. *South* and *North* Direct.
3. *East* and *West* Direct.
4. *South* and *North*, declining { *East*
Or,
West
5. *East* and *West* Direct { *Reclining*
Or,
Inclining.
6. *Equinoctial*, Or *South* Reclining or Inclining to the *Pole*.
7. { *South* direct Reclining or Inclining { less } than the *Pole*.
8. { { more }
9. *Polar*, Or *North* Reclining or Inclining to the *Equinoctial*.
10. { *North* direct Reclining or Inclining { less } than the *Equi-*
11. { { more } noctial.
12. *Equinoctial*, Or *South* Declining *East* or *West* Reclining to
13. *South*
the *Pole*.

- Thus are the several Plains denominated, I shall now shew how the Situation of any Plain may be attained, either in respect of its *Declination* or *Reclination*.

How to find the Reclination and Declination of any Plain.

THe *Reclination* of a *Plain*, is the Arch of that *Vertical* Circle or *Azimuth*, which is perpendicular to the *Reclining Plain*, or that *Azimuth*, in which the *Pole* of the *Reclining Plain* lieth, comprehended between the *Zenith* of the place, and the *Reclining Plain*.



To find which, let ABCD be a *Reclining Plain*, draw first thereon by help of a *Ruler* and *Quadrant*, a line GH parallel to the *Horizon* of the place, which shall be the *Horizontal Line* of the *Plain*, and cross it at right Angles with another right line KS, for the *Vertical Line*

Line of the Plain; to this *Vertical Line* K S, apply a streight Ruler K I, and to that end of it, which lieth clear of the Plain as I, apply a Quadrant as O L I; having a thread and plummet hanging from the Centre at I, then see what number of degrees of the Quadrant are contained between O and L, for so much doth the Plain *Recline* from the *Zenith*.

I I. For the Declination.

The *Declination* of a Plain, is an Arch of the *Horizon* comprehended between the *Pole of the Plain*, and the *Meridian of the Place*. Or it is the distance of the Plain it self, from the prime *Vertical Circle*, or *Azimuth* of East and West.

To find out the Declination of any Plain, there are required two Observations to be made by the Sun at the same instant of time. The first of the *Horizontal distance of the Sun from the Pole of the Plain*, and Secondly, Of the *Suns Altitude*.

1. To find the *Suns Horizontal distance from the Pole of the Plain*. Apply one edge of a Quadrant to the Horizontal line of your Plain, so that the other may be perpendicular to it, and the limb of the Quadrant may be towards the Sun, and hold the whole Quadrant Horizontal (as near as you can conjecture.) Then holding up a thread and plummet at full liberty, so that the shadow of the thread may pass both through the Centre and Limb of the Quadrant, observe then the degrees cut by the shadow of the Thread, and number them from that side of the Quadrant that standeth square or perpendicular to the Plain: For those degrees are the *Horizontal distance* required.

2. This *Horizontal distance* and the *Suns Altitude* being observed at the same time (as near as may be) will help you to the *Plains Declination* by the Rules following.

First, By having the *Altitude*, you may find the *Azimuth*,

muth by the two last *Problemes* of the *Introduction*. Then by comparing the *Azimuth* and this *Distance* together, you may find the *Plains Declination* in this manner.

When you make your *Observations* of the *Suns Horizontal distance*, mark whether the shadow of the thread fall between the *South*, and that side of the *Quadrant* which is perpendicular to the plain.

1. If the shadow fall between them, the *Azimuth* and *Distance* added together, do make the *Declination of the Plain*, and in this case the *Declination* is upon the *same coast* whereon the *Suns Azimuth* is.

2. If the shadow fall not between them, then the difference between the *distance* and *Azimuth* is the *Plains declination*; and if the *Azimuth* be the greater of the two, then the *Plain* declines to the *same Coast* whereon the *Sun* is; but if the *distance* be the greater, then the *Plain* declines to the *contrary Coast*.

And here note, that the *Declination* thus found is always accounted from the *South*, and that all *Declinations* are counted from either *South* or *North*, towards either *East* or *West*, and must never exceed 90 degrees.

1. If therefore the degrees of *declination* do exceed 90, you must take the residue of that number to 180, and that shall be the *Plains declination* from the *North*.

2. If the degrees of *declination* exceed 180, then the excess above 180 degr. gives the *Plains declination* from the *North* towards that *Coast*, which is contrary to the *Coast* whereon the *Sun* is.

I. *Of the Vertical Dialling.*

CHAP. III.

How to draw the Hour-lines upon a Vertical (commonly called Horizontal) Plain.

I Call this Plain *Vertical*, because the Pole thereof is in the *Zenith* or *Vertex* of the Place, although the Plain it self lie in the Plain of the *Horizontal Circle*. And I not only denominate this, but all the other Plains following, by that part of the Sphere in which the Poles and not the Plains themselves lie. But howsoever the Plain be termed, whether *Vertical* or *Horizontal*, the making of the Dial is still the same : And may be made in any known Latitude by the precepts following.

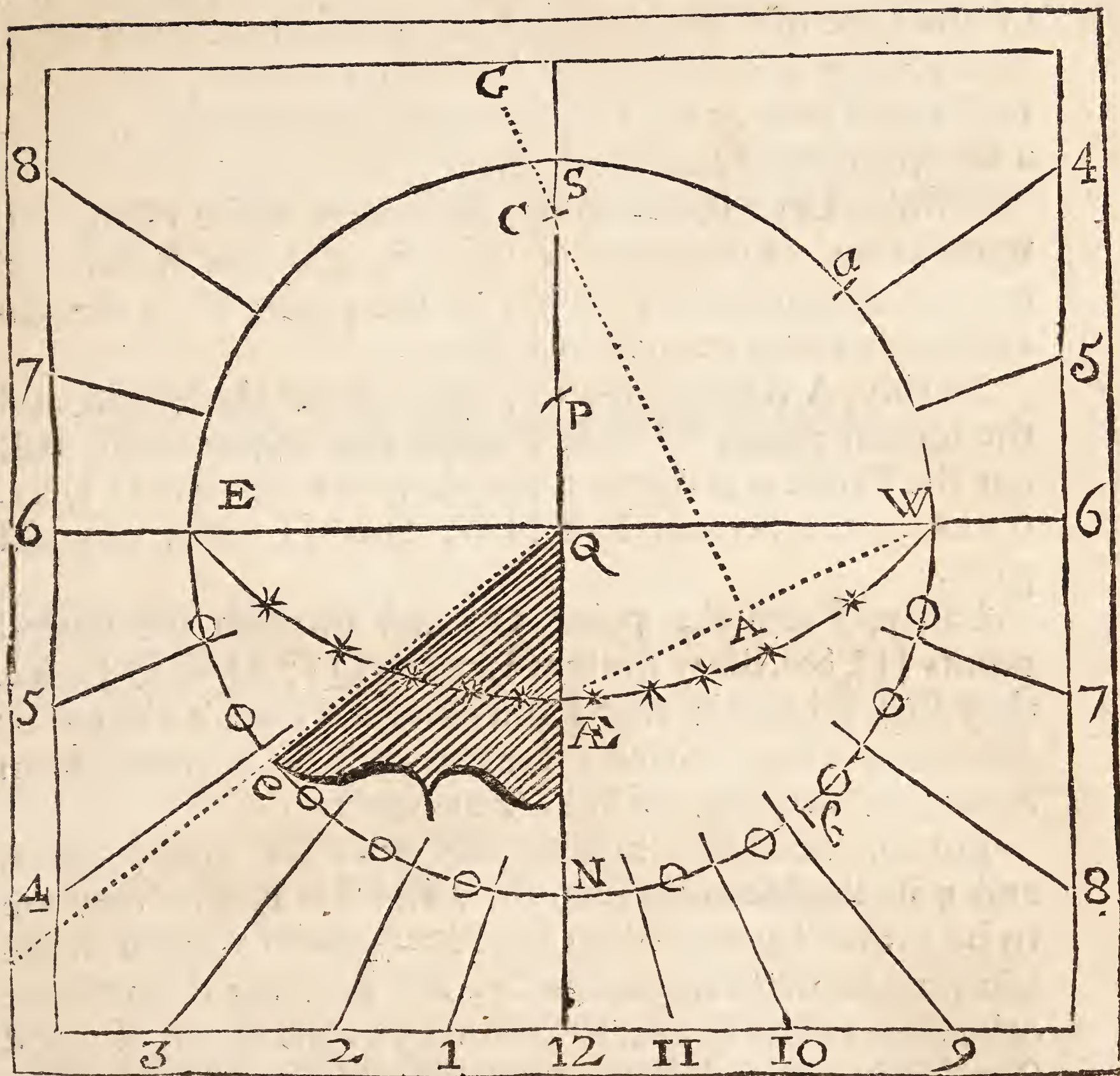
Example, Of a Vertical or Horizontal Plain in the Latitude of London, which is 51 deg. 32 min.

First, Draw a Circle E S W N, which Circle let represent your *Vertical Plain*, cross it in the middle thereof at right Angles with the two Diameters, viz. S Q N, for the Meridian, and Hour-line of 12, and E Q W for the Prime *Vertical* or Hour-line of 6.

Secondly, Because the Latitude of the place is 51 deg. 32 min. take 51 deg. 32 min. out of your Line of Chords, and set that distance from S to *a*, and from W to *b*.

Thirdly, Lay a Ruler from E to *a*, and it will cut the Meridian Line S N, in the point P, which point P is the Pole of the World : And a Ruler laid from E to *b*, will cut the Meridian in the point Æ, so is Æ the point where the Æquinoctial crosseth the Meridian ; and thus have you three points, viz. E, Æ, and W, through which you must draw

*A Vertical or Horizontal Dial for the Latitude of
London, 51 deg. 32 min.*



draw the Æquinoctial Circle $E \text{ } \text{Æ} \text{ } W$, whose centre will always be in the Meridian Line $S \text{ } N$. So that you may easily find it, as hath been before taught, and in this manner also. Draw the Line $\text{Æ} \text{ } W$, which divide in two equal parts in the point A , upon which point A , raise the perpendicular $A \text{ } C$, cutting the Meridian $S \text{ } N$, in the point C , which is the centre of the Æquinoctial Circle $E \text{ } \text{Æ} \text{ } W$, upon which point, and the distance $C \text{ } \text{Æ}$, you may describe it. Fourthly,

Fourthly, Divide the Semicircle E N W, into 12 equal parts at the points $\odot \odot \odot$, &c. beginning at the point N, and setting six on either side thereof. The Semicircle may easily be divided into 12 parts in this manner; for 60 deg. of the Line of Chords will divide it into three equal parts, and 30 deg. will divide each of them into two, that is, into 6 equal parts, and 15 deg. is the half thereof, which is a twelfth part of the Semicircle.

Fifthly, Lay a Ruler to Q, the centre of the Plain, and upon every of these points $\odot \odot \odot$, and the Ruler will cut the *Æquinoctial* E \mathcal{A} W, in the points * * *, &c. dividing that into 12 unequal parts.

Sixthly, A Ruler laid to P, the Pole of the World and the several points * * *, &c. upon the *Æquinoctial*, will cut the Circle representing the plain in the points | | |, &c. dividing the Semicircle E N W, into 12 other unequal parts.

Lastly, From the point Q, and through the several points | | |, &c. draw straight Lines, as Q | 7, Q | 8, Q | 9, &c. they shall all be the true Hour-lines for such a *Vertical* or *Horizontal Plain*. Namely, for twelve of them, that is, from Six in the Morning, till Six at Night.

But for the Hours before, and after Six, that is, for 4 and 5 in the Morning, and for 7 and 8 at Night, they are to be drawn by extending the Hour-line of 7 and 8 in the Morning through the centre Q, and drawing them on the other side of the Plain, so shall they be the Hours of 7 and 8 at Night: — Also the Hour-lines of 4 and 5 in the Evening, being drawn through the centre Q, will become the Hour-lines of 4 and 5 in the Morning.

For the Stile of this Dial, take 51 deg. 32 min. the Latitude of your place, out of your Line of Chords, and set them from N to e, upon the Circle of the Plain, so shall a Line drawn from Q through e, be the *Axis* or *Stile* of the *Dial*, which may be a thin plate of Brass, cut exactly to the quantity of the Angle e Q N. 51 deg. 32 min. and set
per-

perpendicularly upon the Line of 12, or the Meridian S Q N, and thus is your Dial finished.

If into this, or any of the following Dials, you have a desire to insert the Half Hours and Quarters, you may put them in by the very same means, as you did the whole Hours, but then you must divide the Spaces between every of the points $\odot \odot$ into two equal parts for the Half, and into 4 equal parts for the Quarters of Hours, and proceed with putting on of them in all respects as you did with the whole Hours.

II. Of Upright or Erect Plains.

CHAP. IV.

THose Plains are said to be *Erect* or *Upright*, which stand perpendicular to the *Horizon* of the place, whose Vertex or upper part tendeth to the *Zenith*, and their lower part to the *Nadir*, and such are the Walls of Steeples, Churches, Houses, or the like, against which (for the most part) Dials are made.

Of these *Upright* or *Erect Plains* there are two sorts, *viz.* *Direct* and *Declining*.

Those *Erect* or *Upright Plains* are said to be *Direct*, which do directly behold either the true East, West, North, or South points of the *Horizon*, or whose Poles do lie directly in either of them, and these Plains are called *Erect Direct Plains*.

Those *Erect* or *Upright Plains* are said to decline, which do not lie in, or directly behold any of these points, but are situate under some other *Azimuth*, as *South-East*, *North-West*, *North-East*, &c. and these Plains are called *Erect* or *Upright Declining Plains*. Of both which sorts I shall give you Examples. And

I. Of Upright, or Erect Direct Plains.

CHAP. V.

How to draw the Hour-lines upon a Direct South Plain.

That Plain is called, by me, a *Direct South Plain*, which lieth in the prime Vertical Circle, or East and West *Azimuth*, and whose Pole is in the South part of the Meridian, the making whereof differeth nothing from that going before. Only for the height of the Stile, instead of the Latitude you must take the Complement thereof.

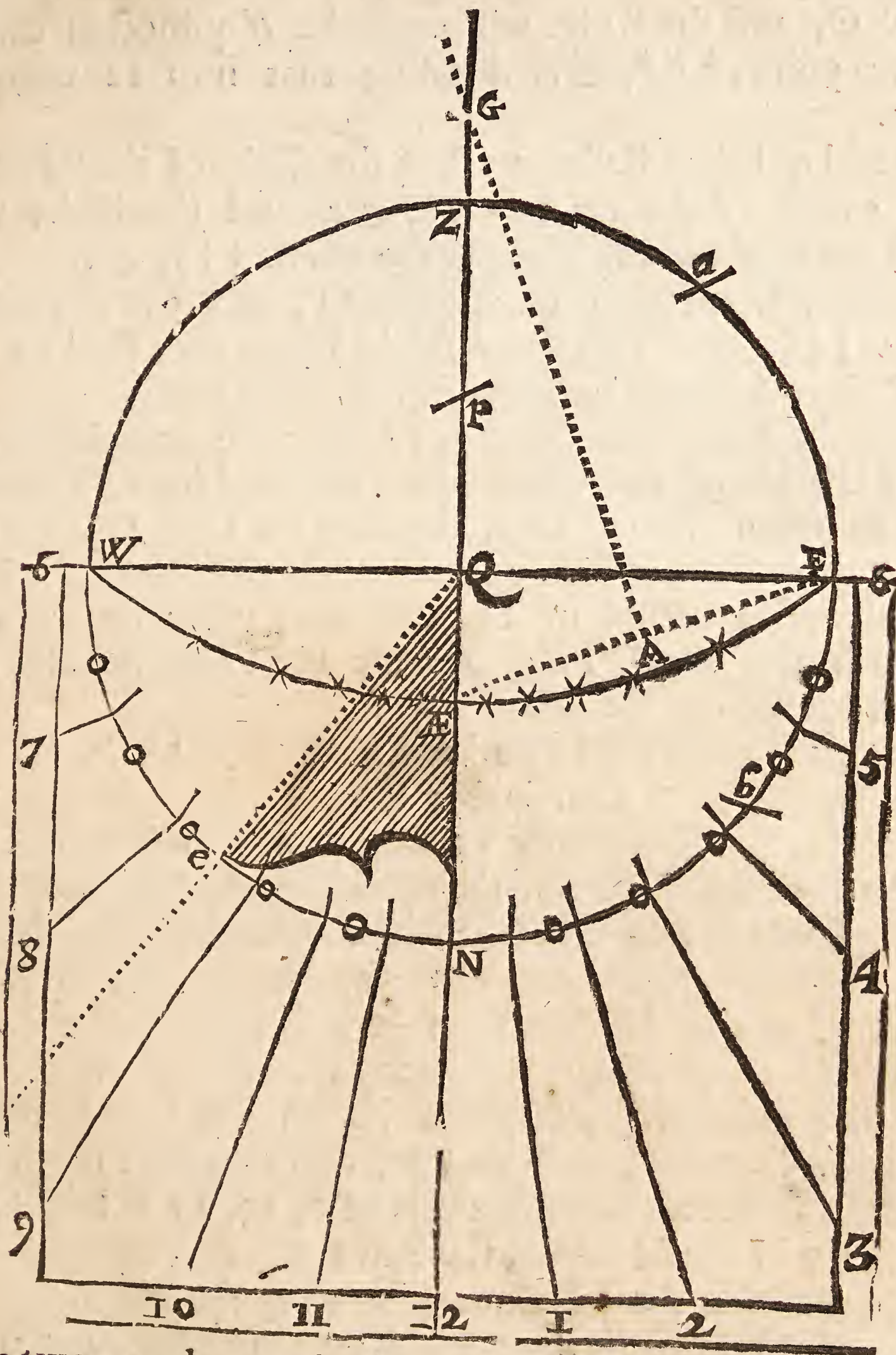
Example, Of a Direct South Plain, in the Latitude of London, 51 deg. 32 min.

First, Draw a Circle Z E W N, representing an upright Direct South Plain, cross it at right Angles with the Diameters Z Q N for the Meridian, or Hour-line of 12, and W Q E for the prime Vertical Circle, or Hour-line of Six.

Secondly, Out of your Line of Chords take 38 deg. 28 min. (which is the complement of the Latitude of the place) and set that distance upon the Dial-plain, from Z to *a*, and from E to *b*, and from N to *e*.

Thirdly, Lay a Ruler from W to *a*, it will cut the Meridian Z N, in the point P, the Pole of the World; and a Ruler also laid from W to *b* will cut the Meridian in *Æ*, so is *Æ* the point through which the *Æ*quinoctial must pass; and for the drawing of it you have three points given, viz. E, *Æ*, and W, and the Centre will always be in the Meridian Line Z N, (extended if need be.) The Centre you may find by the Geometrical way taught at the beginning of the Book. Or thus, draw the Line E *Æ*, and divide it

An Erect Direct South Plain.



it in two equal parts in A, upon A erect the perpendicular AC, extending it till that and the Meridian Line concur in G, so is G the centre of the Æquinoctial Circle EÆW.
 G Fourthly,

Fourthly, Divide the Semicircle E N W into 12 equal parts, at the points $\odot \odot \odot$, &c.

Fifthly, lay a Ruler to Q, and each of these points $\odot \odot \odot$, and the Ruler will cross the *Æquinoctial Circle* in the points $***$, &c. dividing that into 12 unequal parts.

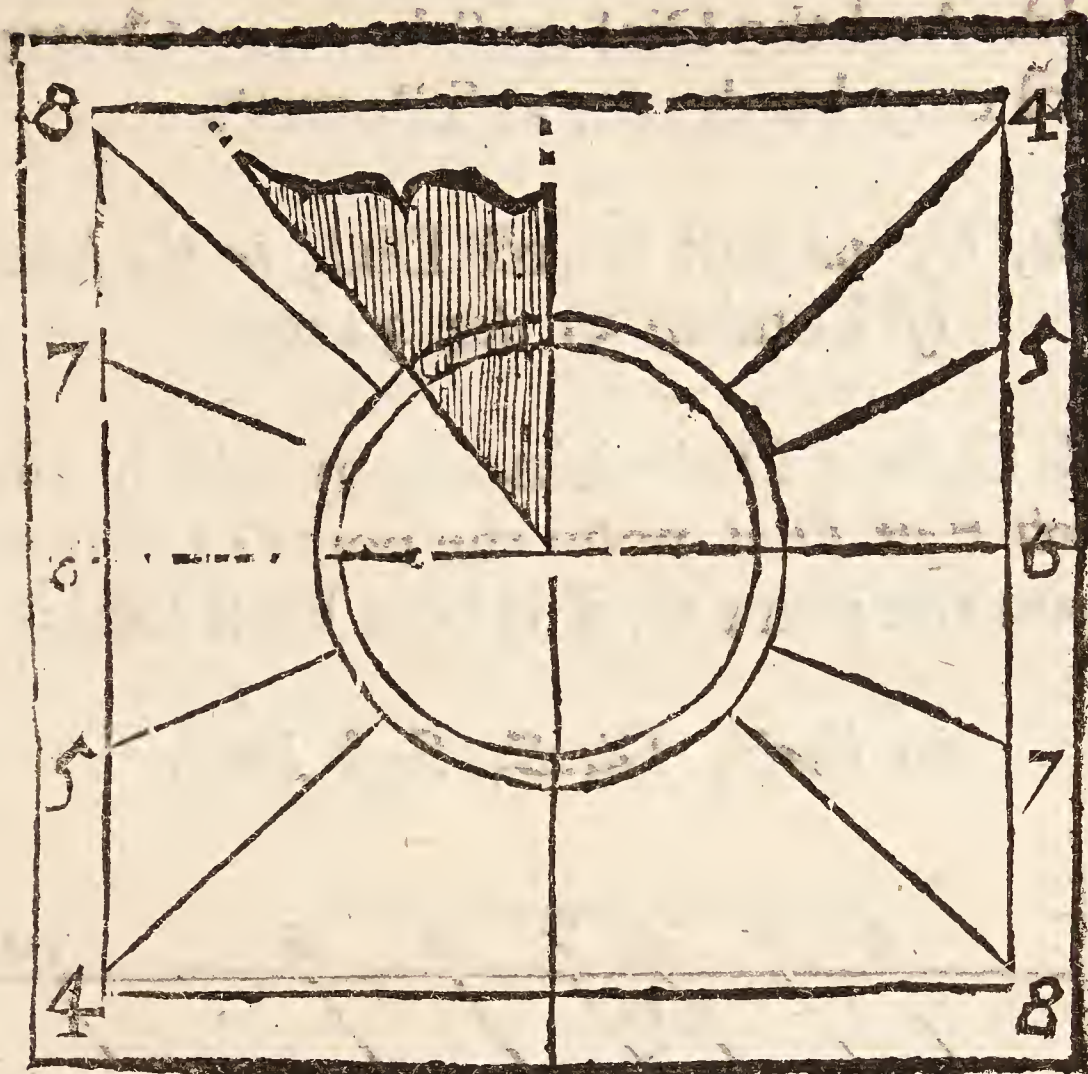
Sixthly, Lay a Ruler to P, (the Pole of the World) and every of the marks $***$, &c. and the Ruler will cross the circle of the Plain in the points $|||$, &c.

Lastly, If through the Centre Q, and the respective points $|||$, &c. You draw Right Lines, they shall be the true Hour Lines of an *Erect Direct South Plain*.

For the Stile, take 38 deg. 28 min. the complement of the Latitude of your Place, out of the Line of Chords, and set them from N to e, drawing the Line Qe for the Axis of the Stile, which must hang directly over the Meridian, or Hour-line of 12, and must point downwards towards the South Pole, because the Plain beholds the South part of the Meridian.

In making this Dial you have made two Dials, for the *Erect Direct North Dial* is but the back-side of the South, it lying in the same Prime Vertical Circle, only as this beholdeth the South part of the Meridian, and hath the South Pole elevated above it, the other beholdeth the North part of the Meridian, and hath the North Pole elevated above it, and as the Meridian Line Z Q N in the South Dial representeth the 12 a Clock Hour-line at Noon, the back-side thereof (namely the North side) representeth the Hour-line of 12 at Midnight, and therefore is not expressed, neither the Hour-lines of 9, 10, 11 at Night, or of 1, 2, 3 in the Morning, the Sun to us never being above the Horizon at those Hours: wherefore the North Dial is only capable of receiving these Hours, namely, 4, 5, 6, 7 and 8 in the Morning, and of 4, 5, 6, 7, and 8 at Night, and (in this Latitude) not of all them neither; for it will never shine upon this Plain at 8 in the Morning, nor at

An Erect Direct North Plain.



4 in the Afternoon, but it is best to put them on, as in the Figure above, that thereby you may know how much it is past 7 in the Morning, and how much it wants of 5 in the Afternoon.

CHAP. VI.

How to draw the Hour-lines upon an Erect, Direct, East, or West Plain.

I Call that an *East* or *West Plain*, which lies in the *Meridian* of the place, and whose Poles lie in the prime Vertical Circle, or *Azimuth* of *East* or *West*.

Now forasmuch as the Plain lieth in the very Meridian Circle, in which also the two Poles of the World are seated,

38 deg. 28 m. the Complement of the latitude of the place, (which is also the height or elevation of the *Æquinoctial*) and set them from E to F, and draw the line D F quite through the Plain. Then, that you may proportion your stile to your Plain, so that you may bring on all the hours from Sun Rising to 11 a Clock, assume two points in the Line F D, one towards the end D (as the point G) for the Hour-line of 11, and another at H, for the Hour-line of 6, and through the points G and H, draw the lines 11 G 11, and 6 H 6, perpendicular to the *Æquinoctial* Line D F. This done, upon the point G, with 60 deg. of the Line of Chords, describe an obscure Arch of a Circle I K, and set thereon 15 deg. of your Line of Chords from I to K, and draw the Line G K, to cut the Line 6 H 6 in the point L. so shall L H be the height of the perpendicular stile proportioned to this Plain.

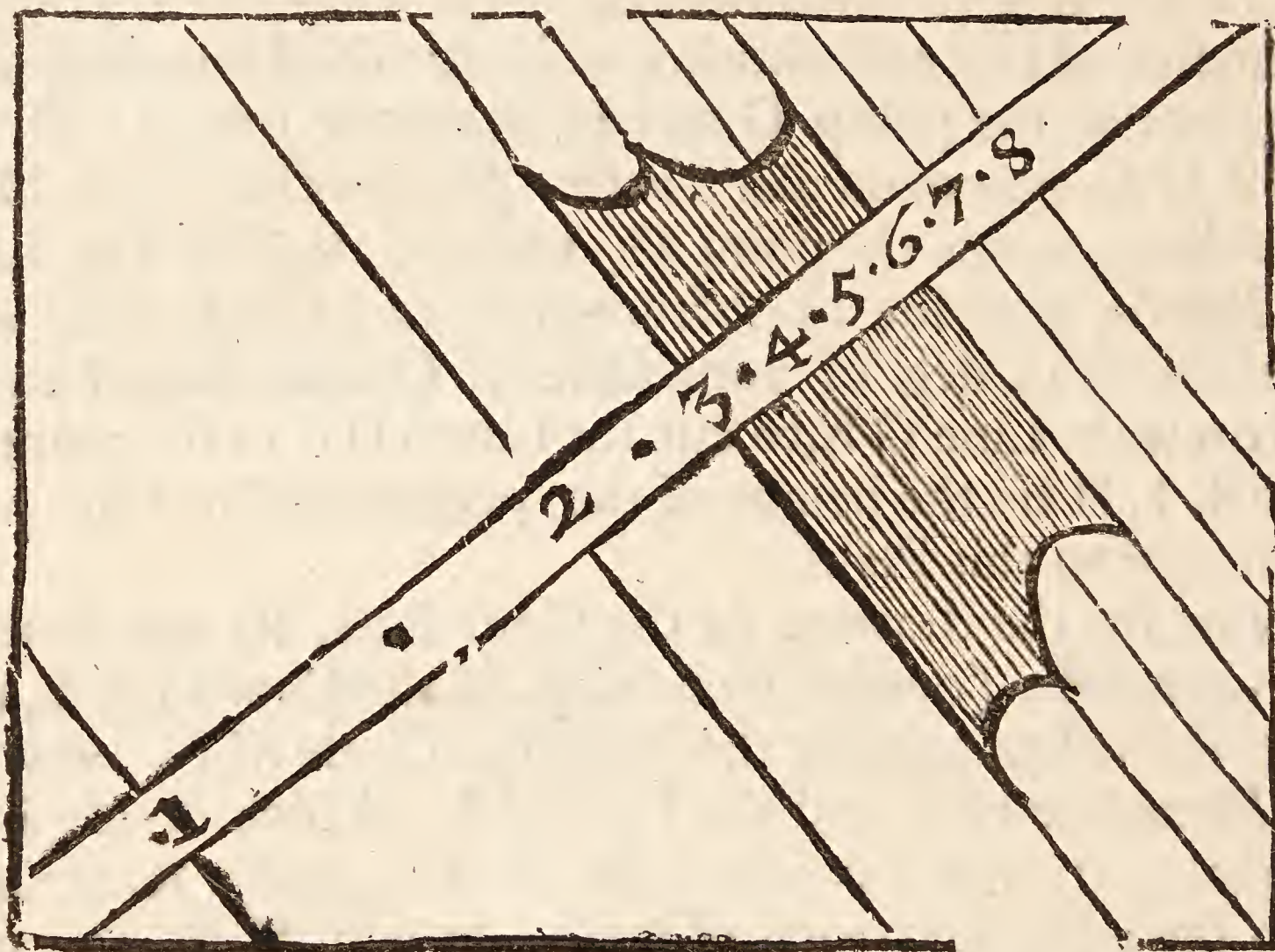
Now for the drawing of the Hour-lines, set one foot of the Compasses (opened to 60 deg. of the Chord) in L, and with the other describe the Arch of a Circle M N, betwixt the Hour-line of 6, and the Line G L. Which divide into 5 equal parts in the points $\odot \odot \odot \odot \odot$, and a Ruler laid from the point L to each of these points $\odot \odot \odot$, &c. will cut the *Æquinoctial* Line H D, in the points * * * * *, through which points draw lines parallel to 6 H 6, as the Lines 7 * 7, 8 * 8, &c. and they shall be the true Hour-lines of an East Plain from 6 in the Morning, till 11 before noon, but for the Hours of 4 and 5 in the Morning, you may put them on by setting the same distances upon the *Æquinoctial* Line before 6, as there is from 6 to 7 and 8, after 6; and through those points draw the Hour-lines of 4 and 5, parallel to the Hour of 6, as you see done in the Figure.

Thus is your Dial finished, and in the making of it you have made two Dials, namely a *West Dial as well as an East*, for it is the same in all respects. Only whereas the Arch E F, through which the *Æquinoctial* passeth in the

East

East Dial, was drawn on the right hand of the Plain, in the West it must be drawn on the left hand, and the Hour-lines of 4, 5, 6, 7, 8, 9, 10, and 11, in the Forenoon on the East Dial, must be 8, 7, 6, 5, 4, 3, 2 and 1 in the Afternoon, upon the West Dial, as in the Figure appeareth.

An Erect, Direct, West Dial.



The Stile of the East or West Dials, may be either a strait Pin of the just length of the Line H O, which is equal to H L in the East Dial, fixed in the point H, upon the Hour-line of 6, and exactly perpendicular to the Plain, shewing the Hours by the shadow of the Apex, or very top thereof.

Or, it may be a Plate of Brass of the same breadth with the distance between the Hour-lines of 6 and 3, which Plate must be set perpendicular upon the Hour-line of Six, and so it will shew the Hour by the shadow of the upper edge thereof, as in this West Dial.

These five Dials here described, *viz.* the *Vertical*, the *South*, *North*, *East*, and *West* Erect, Direct, may be made upon a stone cut square in form of a *Die*, which Body is called a Cube.

II. Of Upright Declining Plains.

CHAP. VII.

How to draw the Hour-lines upon a South or North Erect Plain, Declining either East or West.

THe Upright or Erect Plains, that we have hitherto treated of, are such as did directly behold the four Cardinal or Principal Points of the *Horizon*; namely, the *East, West, North* and *South* Points. All other Upright Plains are said to *decline*, and their Declination is counted from the East or West, towards either North or South, and these Plains are called South or North Erect Plains declining East or West.

Before the Hour-lines can be drawn upon any of these Plains, two things must be given, and three other things must be found——

The Things given must be,

1. The Latitude of the Place.
2. The Declination of the Plain.

The Things required are,

1. The height of the *Pole* (or *Stile*) above the Plain.
2. The distance of the *Sustile* from the *Meridian*, or 12 a Clock Hour-line.
3. The *Plains* Difference of Longitude.

For the finding of these, we must project upon the Plain such Circles of the Sphere (in their true positions) as are requisite for the finding of them, and those Circles are, the *Horizon*, the *Meridian*, and the *Æquinoctial*: which I shall shew how to perform by giving an

Example

Example of a South Erect Plain, declining Westward 24 deg. 20 min. in the Latitude of London 51 deg. 32 min.

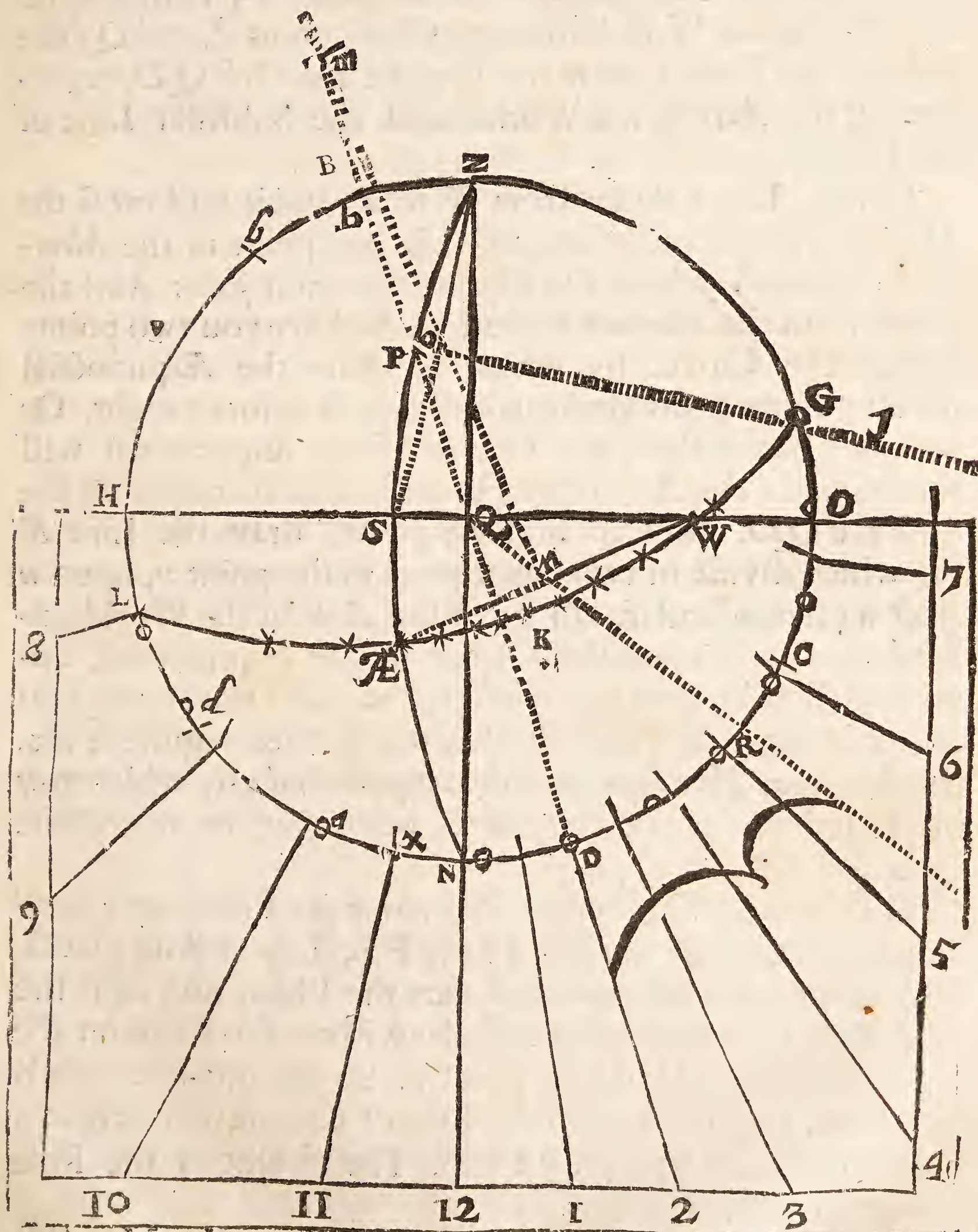
		d.	m.
Data	Latitude of the Place	51	32
	Declination South West	24	20
Quæſita	Distance of the Substile from the Merid.	18	8
	Height of the Pole (or Stile) above the Plain	34	33
	Plains difference of Longitude	30	00

To find which,

First, Describe the Circle Z H N O, representing the declining Plain, cross it at right Angles, with the two Diameters Z Q N, and H Q O, the point Z representing the *Zenith*, and N the *Nadir*, and the line Z Q N, the Vertical or perpendicular-line of the Plain (and Hour-line of 12) and the Line H Q O, is the *Horizontal* Line thereof.

Secondly, Because the Plain declines 24 deg. 20 min. from the South Westward, set 24 deg. 20 min. from N to *a*, and from O to *c*. Then lay a Ruler from Z to *a*, and it will cut the *Horizontal* Line H Q O in S, so is S the South point of the Horizon, through which the *Meridian* must be drawn, and for the drawing of it you have three points, *viz.* Z S and N, and the Centre will always be in the *Horizontal* Line H Q O, extended if need be. Which Centre may be found Geometrically, as is formerly taught, or thus: Draw the right Line Z S, which divide in two equal parts in O, and upon O erect the Perpendicular O G, extending it, till that and the *Horizontal* Line do intersect; for the point of intersection shall be the Centre of the Meridian. Then lay a Ruler from Z to *c*, and it will cut the *Horizon* in W, the West point thereof.

An Upright Plain Declining from the South West-ward 24 deg. 20 min.



H

Thirdly,

Thirdly, Having drawn the *Meridian* and the *Horizon*, take 51 deg. 32 min. out of your Line of Chords, and set them upon your Plain, from H to B, and from N to *d*.

Fourthly, Lay a Ruler upon W, the West point of the *Horizon*, (which is also the Pole of the *Meridian*) to *b*, and it will cut the *Meridian* in the point P, so shall P be the Pole of the World, through which point P, and Q (the Pole of the Plain) draw the straight Line B P Q D, representing the *Axis* of the World, and the Substilar Line of the Dial.

Fifthly, Lay a Ruler from W to *d*, and it will cross the *Meridian* in the point *Æ*, so is *Æ* one point in the *Meridian*, through which the Equinoctial must pass: And the point W in the *Horizon* is another. So have you two points within the Circle, by which to draw the *Æquinoctial* which you may do Geometrically, as is before taught. Or you may find it thus, the Centre of the *Æquinoctial* will always be in the *Axis* of the World, and therefore in the Line B P Q D. Now to find the point, draw the Line *Æ* W, which divide in two equal parts in the point *n*, upon *n* erect a perpendicular, till it cut the *Axis* of the World, extended in *m*. So is *m* the Centre of the *Æquinoctial*, upon which point you may describe it. And thus have you drawn upon your Plain all the three Circles required, *viz.* the *Horizon*, *Meridian*, and the *Æquinoctial*; by which may be found the three Requisites belonging to this Plain. For,

1. To find the height of the Pole above the Plain, represented in the Scheme by the the Line P B. Lay a Ruler to G, where the *Æquinoctial* cuts the Plain, and to P the Pole of the World, the Ruler will cut the Plain on the opposite side in the point *v*. So the distance from B to *v*, measured upon the Line of Chords, will be found to contain 34 deg. 33 min. The height of the Pole above the Plain.
2. To find the distance of the Substile from the *Meridian*,
repre-

represented in the Scheme by the Arches *Z B*, or *N D*. Take in your Compasses the distance *Z B*, or *N D*, and you shall find either of them equal to 18 deg. 8 min. and such is the distance of the Substile from the Meridian.

3. To find the Plains difference of Longitude, represented in the Scheme by the Angle *Æ P K*. Lay a Ruler from *P* to *Æ*, it will cut the Plain in *x*, so the distance between *D* and *x*, measured upon the Line of Chords, will be 30 deg. And such is the Plains difference of Longitude.

Lastly, These Requisites being obtained, we come to the drawing of the Hours; to effect which, lay a Ruler to *P*, the Pole of the World, and *Æ*, the Intersection of the *Æquinoctial* with the *Meridian*, and it will cut the Plain in the point *x*,——At this point *x* begin to divide the Semi-circle *L x G*, into 12 equal parts, at the point $\odot \odot \odot$, &c. Then laying a Ruler to *Q*, and every of these points $\odot \odot \odot$ &c. it will cut the *Æquinoctial Circle*, dividing that into 12 unequal parts in the points ******, &c.——Again, a Ruler laid to *P*, and every of these unequal parts ******, &c. will divide the Plain into 12 unequal parts in the points *| | |* &c. ----- Lay a Ruler to *Q*, and every of these points *| | |*, &c. drawing lines by the side thereof, and they shall be the true Hour-lines proper to such a Declining Plain.

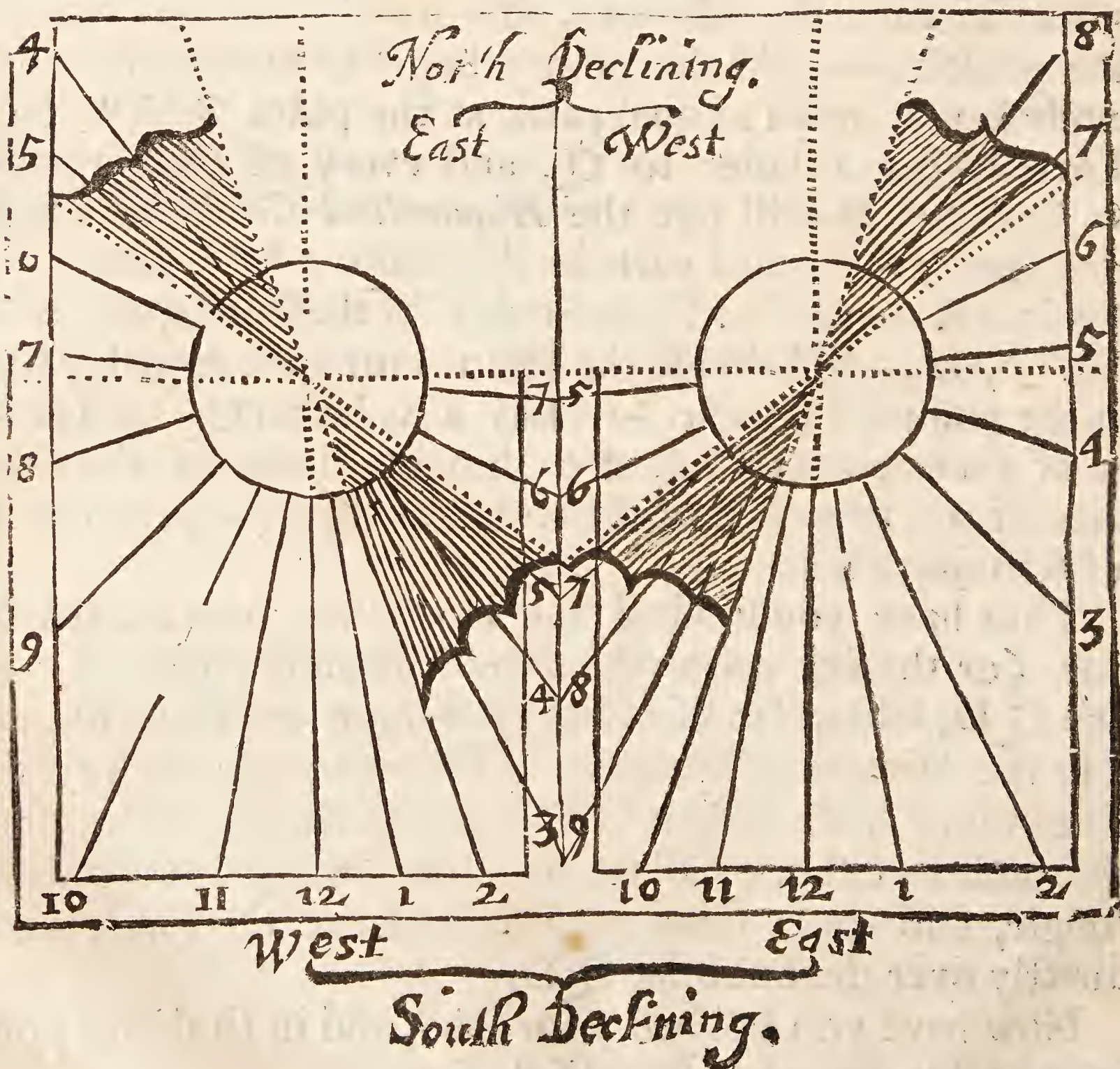
Thus have you finished the Hour-lines, the Substilar-line, (or the line upon which the Stile must stand) is the line *Q D*, falling (in this Dial) just upon the Hour-line of 2 in the Afternoon, because the Plain declined Westward. The Angle of the Stile is *D Q R*, containing 34 deg. 33 m. and must be either of Plate or Wire brought to such an Angle, and must stand perpendicular to the Plain, and directly over the Substilar *Q D*.

Now have you finished your Dial, and in so doing you have in this one made four Dials, viz.

A	{	South declining West	{	d.	m.
		South declining East			
		North declining West			
		North declining East			
				24	20

Only placing of the numbers of the hours and the Stile respectively upon each Plain. For in the South West Plain, which we have now described, the Stile stands upon the hour of 2 in the Afternoon ; in the South East declining as much, it will stand upon the Hour-line of 10 before-noon. And so all the morning hours of the West-decliner will be the Afternoon hours of the East decliner ; and the Afternoon hours of the West decliner, will be Morning Hours

The Four Upright Declining Dials.



of the East decliner: And so the South decliner will produce the North West decliner; and the South West decliner, the North East decliner, by only extending the Hour-lines, Stile and Substile quite through the Centre. And that there my yet remain no doubt, I have drawn all the four Dials in one, by which you may plainly see that there is no difference between them, but what hath been already intimated.

By this Figure you may plainly see, how that one Dial is the Product of all these four, by observing the cautions before delivered. So that it may seem superfluous to say any more concerning these upright declining Dials. Only before I leave them, I will (because these Dials are most in use) give you one other Example of an upright declining Plain, which by reason of its great declination from the Prime Vertical, or its Poles great deviation from the Meridian, causeth the Pole to have but small Elevation, wherefore the Dial (as all such like) must be drawn without a Centre, by the directions following.

CHAP. VIII.

How to draw the Hour-lines upon Upright far Declining Plains, which by reason of the small Elevation, which the Pole hath over such Plains, the Hours (if they be drawn from a Centre) cannot be of any competent distance one from another.

THose Plains which lie near to the Meridian Circle, and whose Poles (consequently) near the prime Vertical Circle, or Azimuth of East or West; the Pole hath but small Elevation above such Plains, so that the Hour-lines (especially those of them which fall near to the Substile) from the Centre, cannot be drawn at any competent distance, without a large extention of them. To remedy which inconvenience, you may draw the Hour-lines for such a Plain at a convenient distance, and in a little room, without

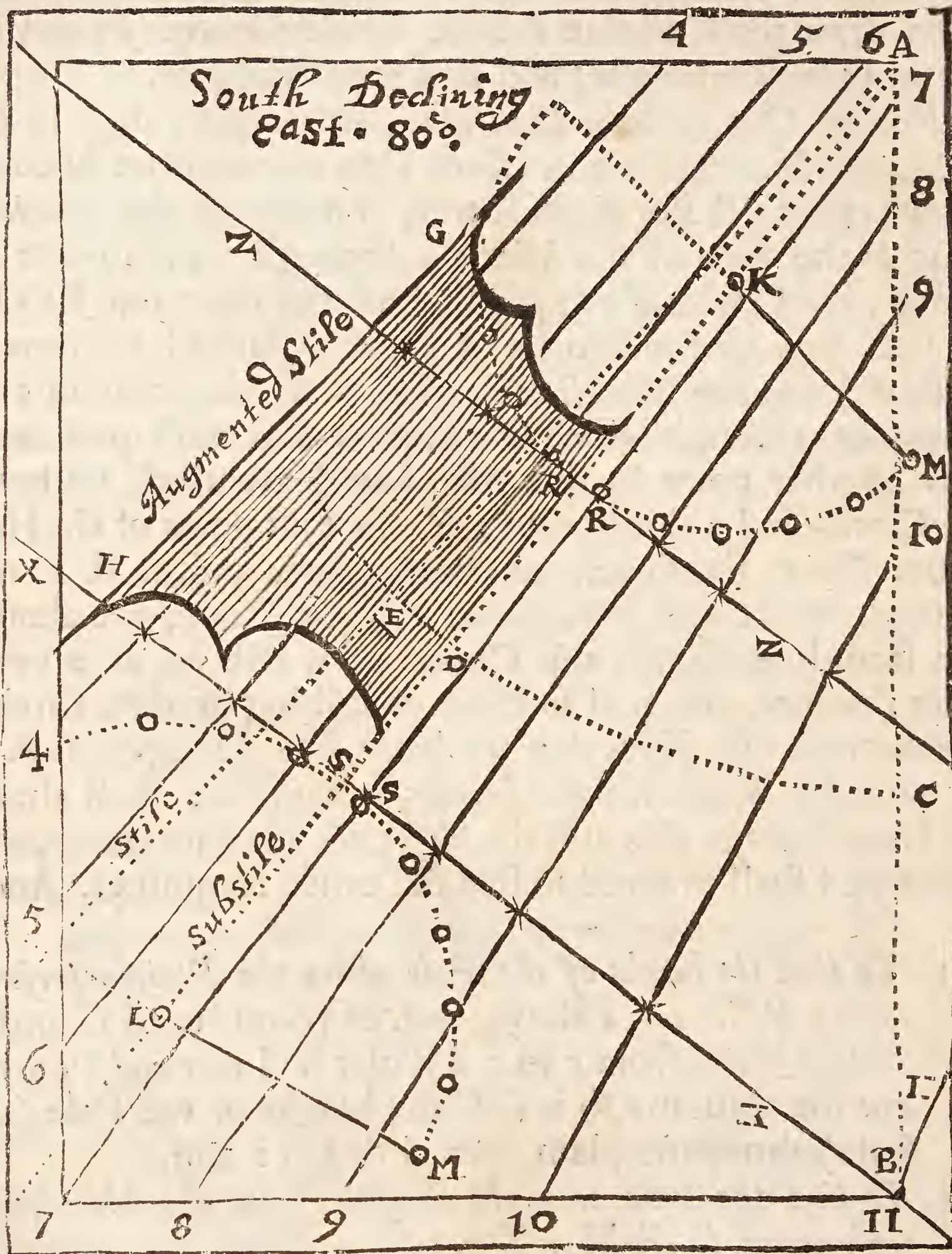
Thirdly, Lay a Ruler to Z and *a*, it will cut the *Horizon* in S, the South point thereof, and a Ruler laid to Z and *b*, will cut the *Horizon* in E, the East point thereof.

Fourthly, Having the three points Z S and N, through them draw the Meridian Z S N, whose Centre (by any of the ways before taught) will be found to be at *m*.

Fifthly, Out of your Line of Chords take 51 deg. 32 m. the Latitude, and set them from O to *c*, and from N to *d*. Then laying a Ruler from E to *c*, it will cut the Meridian in P the Pole of the World; through which point P and Q, the Centre of the Plain, draw the right line P Q B, for the Axis of the World. Also, the Ruler laid from E to *d*, will cut the Meridian in Æ, so is Æ one point in the Meridian, through which the Æquinoctial must pass, and R is another point in the Meridian (extended) without the Circle, and a third point is E, the East point of the Horizon. Now forasmuch as these three points R E Æ, through which the Æquinoctial is to be drawn, are almost in a strait line, so that the Centre of it will be at a very great distance, we will forbear describing of that Circle, and content our selves that we have found the points R E Æ, through which it should pass; because we shall draw the Hour-lines in this and the like cases by other means, and therefore I shall proceed to find the other Requisites. And,

1. To find the height of the Pole above the Plain represented by P C. — Take 90 deg. of your Line of Chords, and set them from *c* to *e*, a Ruler laid to *e* and P, will cut the plain in *o*, so is O C the height of the Pole (or Stile) above the plain, viz. 6 deg. 12 min.
2. To find the distance of the Substile from the Meridian, represented by B N or Z c. — Take the distance B N or Z C (which is equal thereto) in your Compasses, and measure it upon your Line of Chords, so you shall find it to contain 38 deg. 4 min. which is distance of the Substile from the Meridian.

An Erect South Plain Declining Eastward 80 deg.



3. To find the Plains difference of Longitude, represented by the Angle $\angle P \text{ } \text{Æ}$, — Lay a Ruler upon P and Æ , it will cut the Plain in g, the distance g B, measured

measured upon the Line of Chords, will contain 82 d. 8 min. the *Plains difference of Longitude*.

These three Requisites being thus found, I will now proceed to draw the Dial without any regard had to the Centre.

How to draw the Hour-lines upon the Plain.

First, Draw a right line A B, for the perpendicular line of your Plain, and upon A as a Centre, with 60 deg. or the Radius of your Chord, describe an obscure Arch of a Circle C D E, and thereon from C to D, set 38 deg. 4 m. the *Substiles distance from the Meridian* before found, and draw the Line A D for the Substile, quite through the Plain.

Secondly, Take 6 deg. 12 min. the *height of the Pole above the Plain* from your Chord, and set them upon the same Arch from D to E, and draw the line A E for the *Stile*.

Thirdly, Forasmuch as the Stile A E in this case is but of small Elevation, viz. but 6 deg. 12 min. Draw the line G H parallel to A E, at such convenient distance, as you shall think fit, for your new (or augmented) *Stile*, to stand from your Substile A D.

Fourthly, Assume any two points in the Substile A D, as R and S, and through these two points draw two infinite right Lines, both of them at right Angles to the Substilar line A D, as the lines Z Z, and X X.

Fifthly, From the point R, take with your Compasses the least distance to the new augmented Stile G H, and set that distance upon the Substilar line, from R to K: Also, from the point S, take the least distance to the new Stile G H, and set that distance also upon the Substilar line from S to L.

Sixthly, Upon the two points K and L (as upon two Centres) with 60 deg. or the Radius of the Line of Chords, describe two portions of Circles, and in either of them set
I off

off 82 deg. 8 min. *the Plains difference of Longitude*, as from S to M, and from R to M, both on the same side of the Substilar line, on which the perpendicular line of the Plain A B was drawn.

Seventhly, Divide either of the Semicircles last drawn, into 12 equal parts, at the points $\odot \odot \odot$, &c. beginning this division in either of them, at the point M.

Eightly, Lay a Ruler to the point L, and every of the divisions $\odot \odot \odot$, &c. and the Ruler will cut the Contingent or *Æquinoctial* line X X, in the points $***$, &c. Also a Ruler laid to K, and each of the points $\odot \odot \odot$, &c. will cut the other Contingent Z Z, in the points $***$, &c.

Lastly, Lines drawn from the point * in one Contingent line, to the point * in the other Contingent line, each to his correspondent (which the Substilar line will direct you how to do) those lines shall be the true Hour-lines belonging to such a declining Plain, and be drawn as in the Figure you see done, at a competent distance one from another, without any relation at all had to the Centre of the Dial.

Thus have you finished your Dial, and in the making of this, you have made a South declining West 80 deg. also; for if you turn the Paper, and look through it, it will on the back-side be a South declining West 80 deg. only the Forenoon hours in this, must be the Afternoon hours in that: Nay, in rigour, you have in this one Dial made four, viz. a North declining either East or West, if you well observe what was said and done in the last Chapter.

And thus have I done with all *Upright*, or *Erect Plains*, either *Direct* or *Declining*. I shall now proceed to shew you how to inscribe Hour-lines upon such Plains as are not Upright, but *Recline* from the *Zenith*, and of them there are such as are *Direct*, and such as do *Decline*.

III. Of Reclining Plains.

CHAP. IX.

AS in Upright Plains there were two Varieties, viz. *Erect Direct*, and *Erect Declining*. So are there of *Reclining Plains* also. For such *Reclining Plains* as do directly behold either the true East, West, North or South points of the Heavens, that is, whose Poles lie, either in the *Meridian*, or *Prime Vertical Circle* of the place, are called *Direct Reclining Plains*.

Again, Those *Reclining Plains*, which do not directly lie in or their Poles be not in the *Prime Vertical* or *Meridian Circles* of the place, but deviate therefrom, are called *Declining Reclining Plains*. Of both which sorts I shall give you an account, and the manner of inscribing Hour-lines upon them, for in these Plains there is far more variety, than there was in *Upright* or *Erect Plains*.

Of Direct Reclining Plains, &c.

I. Of East and West Recliners.

CHAP. X.

How to draw the Hour-lines upon a Direct East or West Reclining or Inclining Plain.

AS in Upright Declining Dials, Two things must be given, and Three things must be found, before the *Hour-lines* could be drawn. In these direct Reclining Plains Two things must also be given, and Three must be found, before the Dial can be made.

The Things that must be given are,

1. The Latitude of the Place.
2. The Reclination of the Plain.

The *Reclination* of a Plain (as hath been before declared) is the Arch of an *Azimuth* or *Vertical Circle*, intercepted between the *Zenith* of the place, and the *Reclining Plain*.

Example, Of an East or West Plain, Reclining 35 deg. in the Latitude of London 51 deg. 32 min.

		d.	m.
Data	{ Latitude of the Place	51	32
	{ Reclination of the Plain	35	00

Quæſita { The height of the Pole above the Plain.
 { The distance of the Subſtile from the Meridian.
 { The Plains difference of Longitude.

First, Draw the Circle N E S R, representing the Reclining Plain, and croſs it with the two Diameters N Q S, the Horizontal Line of the Plain, and Hour-line of 12 a Clock, and E Q R for the Prime Vertical Circle.

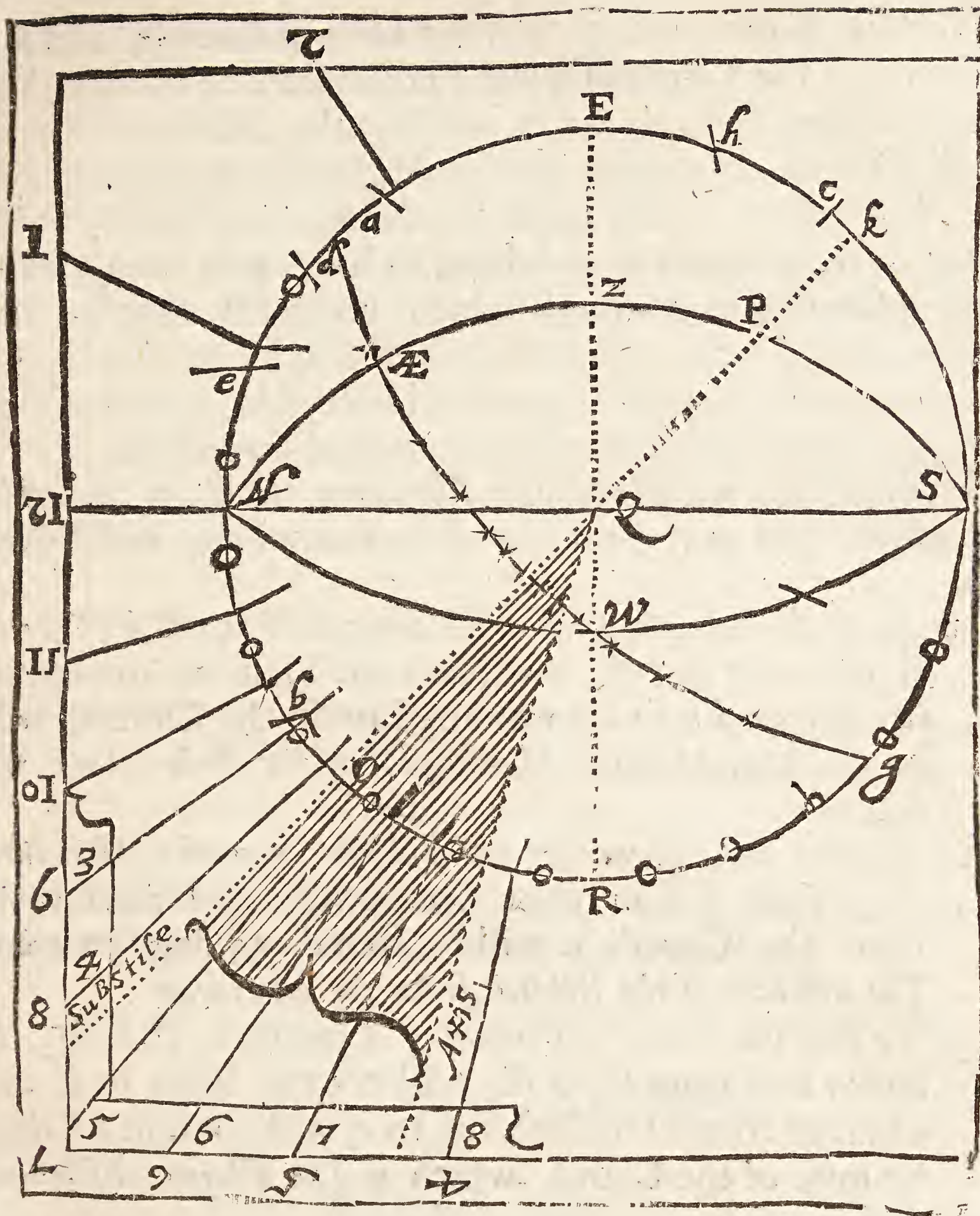
Secondly, Because the Plain reclines 35 deg. take 35 deg. out of your Line of Chords, and ſet them from E to *a*, and from N to *b*.

Thirdly, Lay a Ruler from S to *a*, and it will cut the prime Vertical Circle in Z, ſo is Z the *Zenith* of the place---- Also a Ruler laid from S to *b*, will cut the ſame Vertical Circle in W, by which point the Horizon of the place muſt be drawn.

Fourthly, The points Z and W being found, you have three points through which you muſt deſcribe the *Meridian*, viz. N Z and S; and as many alſo through which you muſt draw the *Horizon*, namely, N W and S. The Centres of both which Circles will fall in the Line E Q R, (extended if need be) and the manner how to find them hath been often enough already taught.

Fifthly,

East and West Inclining.



Fifthly, Because the Latitude of the place is 51 deg. 32 min. Take 51 deg. 32 min. from your Line of Chords, and set them upon your Plain from S to c. Then lay a Ruler upon W the West point of the *Horizon*, and the point c, the Ruler will cross the *Meridian Circle* in P the Pole of the World; through which point P and Q, the Centre
(or

(or pole of the Plain) draw the right line PQ , which shall be the *Axis of the World*, and Substilar Line of your Dial.

Sixthly, Take 90 deg. of your Line of Chords, and set them upon the Circle of your Plain from c to d , then lay a Ruler from W to d , and it will cut the *Meridian Circle* in \mathcal{A} , so is \mathcal{A} one point in the *Meridian*, through which the *Æquinoctial Circle* must be drawn, and W the West point of the *Horizon* is another; so have you two points within the Circle, through which you must describe the *Æquinoctial Circle*, whose Centre will be in the Line PQ , the *Axis of the World*, (extended if need be) the manner how to find it hath been already taught several ways.

Having thus projected the *Meridian*, *Horizon* and *Æquinoctial*, you may find the three Requisites, as followeth.

1. *To find the height of the Pole above the Plain* Pk , Lay a Ruler to g and P , it will cut the Plain on the opposite side in h ; so kh measured upon the Chords, will be 26 deg. 41 min. *The height of the Pole above the Plain.*
2. *To find the distance of the Substile from the Meridian* Sk , Take Sk in your Compasses, and measure it upon the Chord, it will be found 45 deg. 52 min. *The distance of the Substile from the Meridian.*
3. *To find the Plains difference of Longitude*, $\mathcal{A}PQ$, A Ruler laid from P to \mathcal{A} , will cut the Plain in e , the distance from O the Substile, to e , will contain 66 deg. 27 min. of the Chord, which is *The Plains difference of Longitude.*

These *Requisites* being obtained, you may proceed to find the Hour distances upon the Plain in this manner.

Seventhly, Lay a Ruler to P the Pole, and \mathcal{A} the intersection of the *Meridian* with the *Æquinoctial*, and it will cut the Plain in e . At e begin to divide the Semicircle into 12 equal parts, at the points $\odot \odot \odot \&c.$

Eighthly,

Eightly, Lay a Ruler to Q, and the several points $\odot \odot \odot$ &c. and it will cut the *Æquinoctial* Circle in the points $* * *$ &c. dividing that into 12 equal parts.

Ninthly, Lay a Ruler to P, and the several points $* * *$ &c. and it will cut the Plain in the points $| | |$ &c.

Lastly, If from the Centre Q, you draw right Lines through the points $| | |$ &c. they shall be the true Hour-lines belonging to your Reclining Plain.

And thus have you finished your Dial, and also in it Four Dials: For the Dial as it here stands in the Scheme, is properly an East and West Incliner, but being turned upside down, as you see the hours numbred, and the word *Zenith* standing upwards, it is an *East Recliner*; and if the Hour-lines be turned (or supposed to stand) on the right hand of the *Prime Vertical* Line E Q R, as in this Scheme they do on the left hand, and the hours of 4, 5, 6, &c. in the Morning, changed to 8, 7, 6, &c. in the Evening, the Plain is then a *West Recliner*. And if the Hour-lines be drawn through the Centre of either of them, the Plains then become East and West *Incliners*; the hours and Substile in all retaining the same place, only the denominations of the Hours changed, &c. you must remember, that in all East and West Recliners, the *North Pole* is elevated, and in all Incliners (opposite to them) the *South Pole*.

I I. Of South Recliners.

CHAP. XI.

How to draw the Hour-lines upon Direct South Reclining or Inclining Plains.

IN the East and West Reclining and Inclining Plains, before described, the *Meridian*, or 12 a Clock Hour-line, did lie in the *Horizontal* Line of the Plain, and the Poles thereof

thereof in the *Prime Vertical Circle*. So (on the contrary) in these South and North Reclining and Inclining Plains, their *Horizontal* line lieth in the *Prime Vertical Circle*, or hour of 6, and their Poles in the *Meridian*, and from hence they receive their denomination.

Of these Direct Reclining Plains there are *Six Varieties*, viz. three of South Recliners, and as many of North Recliners. For,

1. The South Plain may Recline, so as it may just fall in the Axis of the World, and so pass through the Poles of the World, and then it is called an *Æquinoctial Plain*, because the poles thereof lie in the *Æquinoctial Circle*, and neither of the poles have any Elevation above it, wherefore the Hour-lines must be all parallel one to the other, and all of them to the Axis of the World, and the Dial must be drawn as the Erect Direct East or West Dials were. Only, whereas the Stile stood upon the Hour-line of 6 in the East and West, in these plains it must stand up the Hour-line of 12, and be of equal height with the distance between the hours of 12 and 9, or 12 and 3, which are equidistant from the *Meridian*.

2. Or *Secondly*, The South Plain may so Recline, that it may fall between the *Zenith* and the North Pole, and then is the South Pole elevated above such a Plain. Or,

3. The North Plain may so Recline, that it may fall between the Horizon and the North Pole, and then is the North Pole Elevated.

Examples of these three Varieties of South Reclining Plains do here follow.

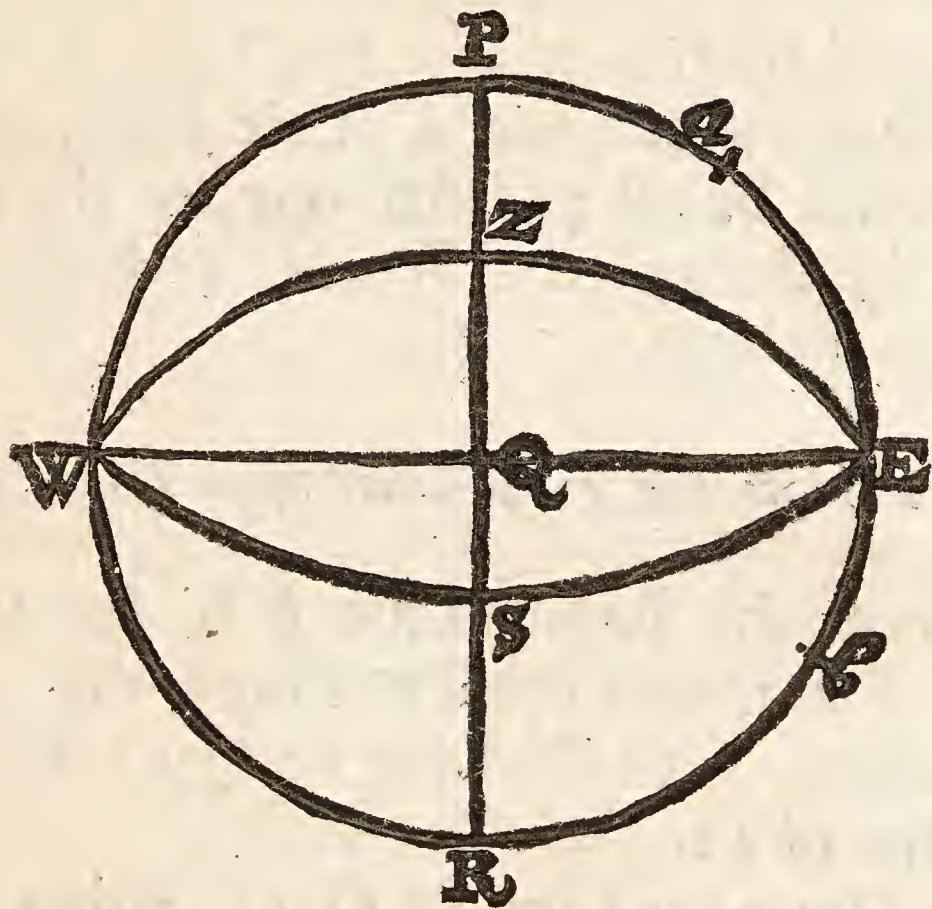
The First Variety.

CHAP. XII.

*How to draw the Hour-lines upon an Æquinoctial Plain,
Reclining just to the Pole.*

Suppose a South plain should Recline 38 deg. 28 min. in the Latitude of *London* 51 deg. 32 min.

First, Draw the Circle *W P E R*, representing your Reclining plain, and cross it with the two Diameters *P Z S R*, for the *Meridian*, and *W Q E*, the *Horizontal* line of the plain.



Secondly, Because the plain Reclines 38 deg. 28 min. take 38 deg. 28 min. out of your Chord, and set them from *P* to *a*, and from *E* to *b*.

Thirdly, Lay a Ruler from *W* to *a*, it will cut the *Meridian* in *Z*, so is *Z* the *Zenith* of the place, through which point, and the points *W* and *E* (the *West* and *East* points of the *Horizon*) draw the prime Vertical Circle *W S E*.

Fourthly, Lay a Ruler from W to *b*, and it will cut the *Meridian* in S, through the points W S and E, draw the Horizon of the place W S E.

Fifthly, Because the Latitude of the place is 51 deg. 32 min. set 51 deg. 32 min. upon your plain from E to *a*, and it will cut the *Meridian* P Q R, in the point Z the *Zenith*, then (because the pole of the World is removed from the *Zenith*, (always) so much as is the Complement of the Latitude, which here in this Example is 38 deg. 28 min.) take therefore this distance 38 deg. 28 min. and set it upon your plain from *a*, and you shall find, that the Compass-point will directly fall in the point P, which is the Pole of the World and is the very place where the Reclining Plain, and the *Meridian* of the place do intersect, which clearly demonstrates, that the Pole hath no Elevation above this Plain, and by this means, the Line W Q E, becomes to be the *Æquinoctial*, and a strait Line, wherefore the Hour-lines must be all parallel one to the other, and all of them to the Axis of the World, and the Dial must be drawn in this manner.

To draw the Hour-lines upon the Plain.

First, Draw the Right Line A B, for the *Horizontal* Line of the Plain, and cross it about the middle thereof at Right Angles, with the Line 12 Q 12 for the *Meridian* and Hour-line of 12.

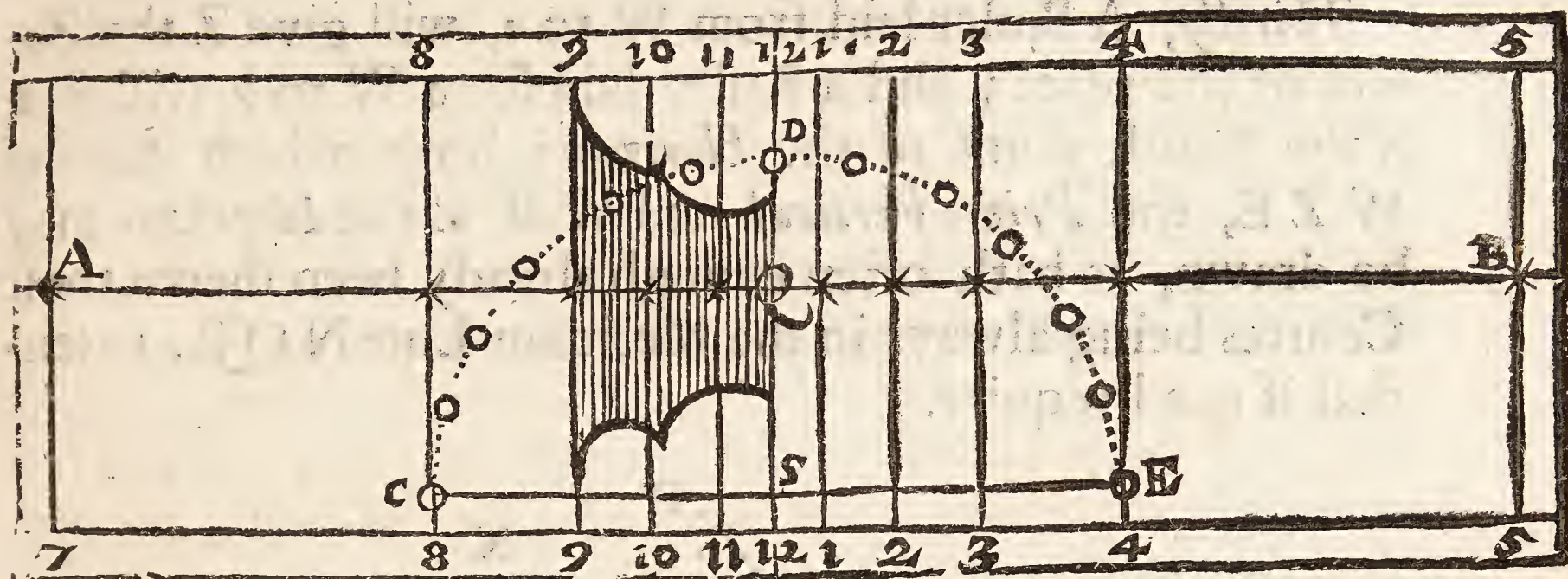
Secondly, Upon the Line 12 Q 12, either above or below Q, assume any point, as S, and setting one foot of your Compasses therein (it being opened to the Radius of your Line of Chords) describe the Semicircle C D E, which divide into 12 equal parts, beginning at D.

Thirdly, Lay a Ruler to S, and the several points ○ ○ ○ &c. and it will cross the *Æquinoctial* Line A B, in the points * * * &c.

Lastly, Through these points * * * &c. draw Right Lines
all

all parallel to the Line 12 Q 12, and so is your Dial finished.

A Direct Æquinoctial Dial.



The Stile may be either a strait Pin, of the length of the line Q S, set perpendicular to the Plain upon the point Q; the shadow of the top thereof only giving the Hour. Or it may be a plate of the breadth of the distance that is between the Hour-lines of 12 and 3, or 12 and 9. and then will the shadow of the upper edge thereof, give the hour of the day.

The Second Variety.

CHAP. XII.

How to draw the Hour-lines upon a Direct South Reclining Plain, which falls between the Zenith and the Pole.

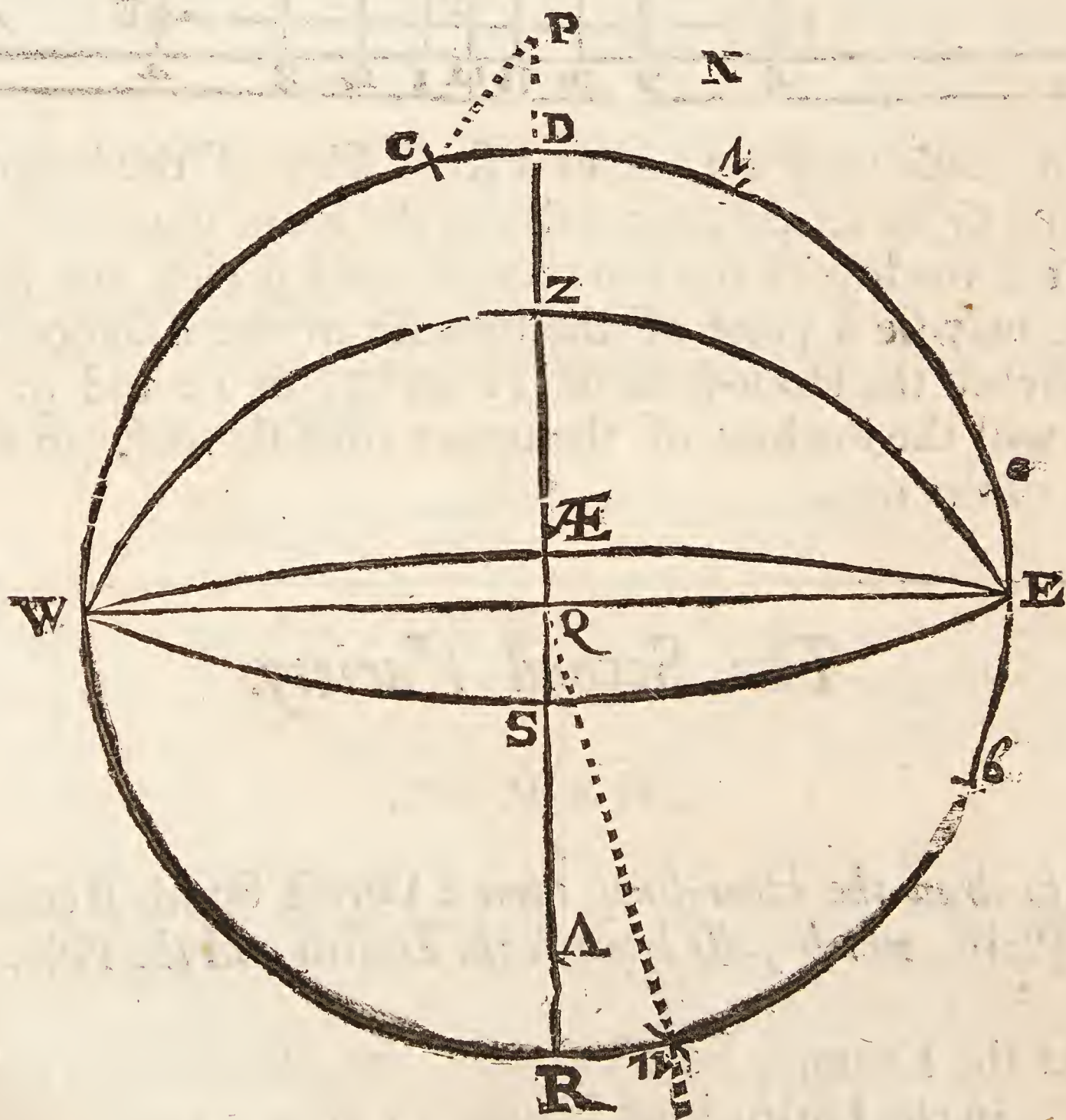
Let the Example be of a South Plain Reclining 25 d. in the Latitude of London 51 deg. 32 min.

First, Draw the Circle W D E R, representing your Reclining Plain, cross it with the two Diameters N R, K 2 for

for the *Meridian* and Hour-line of 12, and W E, for the *Horizontal* line of the Plain, and Hour-line of Six.

Secondly, Take 25 deg. the Plains Reclination, out of your Line of Chords, and set that Distance from D to *a*, and from E to *b*.

Thirdly, A Ruler laid from W to *a*, will give Z the *Zenith* of the place; and a Ruler laid from W to *b*, will give S the South point of the *Horizon*; both which Circles W Z E, the *Prime Vertical* and W R E the *Horizon*, may be drawn, as hath often enough already been shewn, their Centres being always in the Meridian Line N Q R, extended if need require.



Fourthly, Because the Pole of the World is always distant from the *Zenith*, the Complement of the Latitude of the

the place, *viz.* here at *London*, 38 deg. 28 min. Take (therefore) 38 deg. 28 min. out of your Line of Chords, and set them upon your Plain from *a*, the point which found the *Zenith* to *C*.

Fifthly, Lay a Ruler from *W* to *C*, and it will cut the *Meridian* *NQR*, (being thus extended) in *P*, so is *P* the North Pole of the World, and because it falleth without Plain, it is evident by the Scheme, that this Reclining Plain passeth through the *Meridian*, between the *Zenith* and the Pole. And again, because the North Pole *P* falleth without the Plain, it also demonstrates that the South Pole must be elevated above this Plain. Wherefore,

Sixthly, To find the point of the South Pole upon the *Meridian* line *NQR*, do thus. Because the two Poles are 180 deg. distant from each other, *viz.* two Quadrants, or twice 90 deg. Take therefore 90 deg. out of your Line of Chords, and set them twice upon your Plain from *C*, *viz.* first from *C* to *e*, and then from *e* to *n*, so shall the 180 deg. end in *n*: And a Ruler being laid from *W* to *n*, shall cross the *Meridian* in *A*, the South Pole; so is the South Pole *A*, elevated above the Reclining Plain, the quantity of *AR*, which is equal to the Arch *Rn*, which measured upon the Line of Chords will be found 13 deg. 28 min.

Seventhly, Lay a Ruler from *W* to *e*, and it will cut the *Meridian* in *Æ*, so is *Æ* that point in the *Meridian* through which the *Æquinoctial* must pass. As also through the points *E* and *W*, the East and West points of the Horizon.

Eighthly, For the Hour-lines, They are to be drawn in all respects as the Hour-lines were upon the upright South Plain, without any alteration, only there the Stile was elevated according to the Complement of the Latitude 38 deg. 28 min. here it must be elevated only 13 deg. 28 min. as in the Scheme. The manner how the Hour-lines are to be put on, I shall only repeat, but I shall forbear drawing them, leaving that to your own practice, in regard there is no alteration at all from the Erect Direct South Plain.

Where-

Wherefore divide the Semicircle of your Plain W R E into 12 equal parts, (beginning at R, and so 6 equal parts on either side of the Meridian N Q R.) Then lay a Ruler to Q, and every of those 12 divisions, it will divide the Æquinoctial into 12 unequal parts. A Ruler laid from P to every of those unequal parts in the Æquinoctial, will divide the Plain into 12 other unequal parts, through which last 12 unequal parts, and the Centre Q, if you draw right Lines, they shall be the true Hour-lines proper for the Plain.

And here by the way note, for that the Æquinoctial Circle in this Scheme is a very oblique Arch, the Centre of it will be very remote, and the Hour-spaces upon it (as also upon the Plain) will be very close together in these small draughts, which is occasioned by the small Elevation that the South Pole hath above this Plain, *viz.* but 13 deg. 28 min. which you might find without drawing of the Scheme by subtracting 25 deg. the Plains Declination represented in the Scheme by the Line (or Circle) D Z, from Z P, the Complement of the Latitude of the place. And therefore, foreseeing that the Pole hath but small Elevation above the Plain, and also what Pole, whether North or South that is elevated: The better way will be to augment the Stile, and to draw the Dial according to these following Directions.

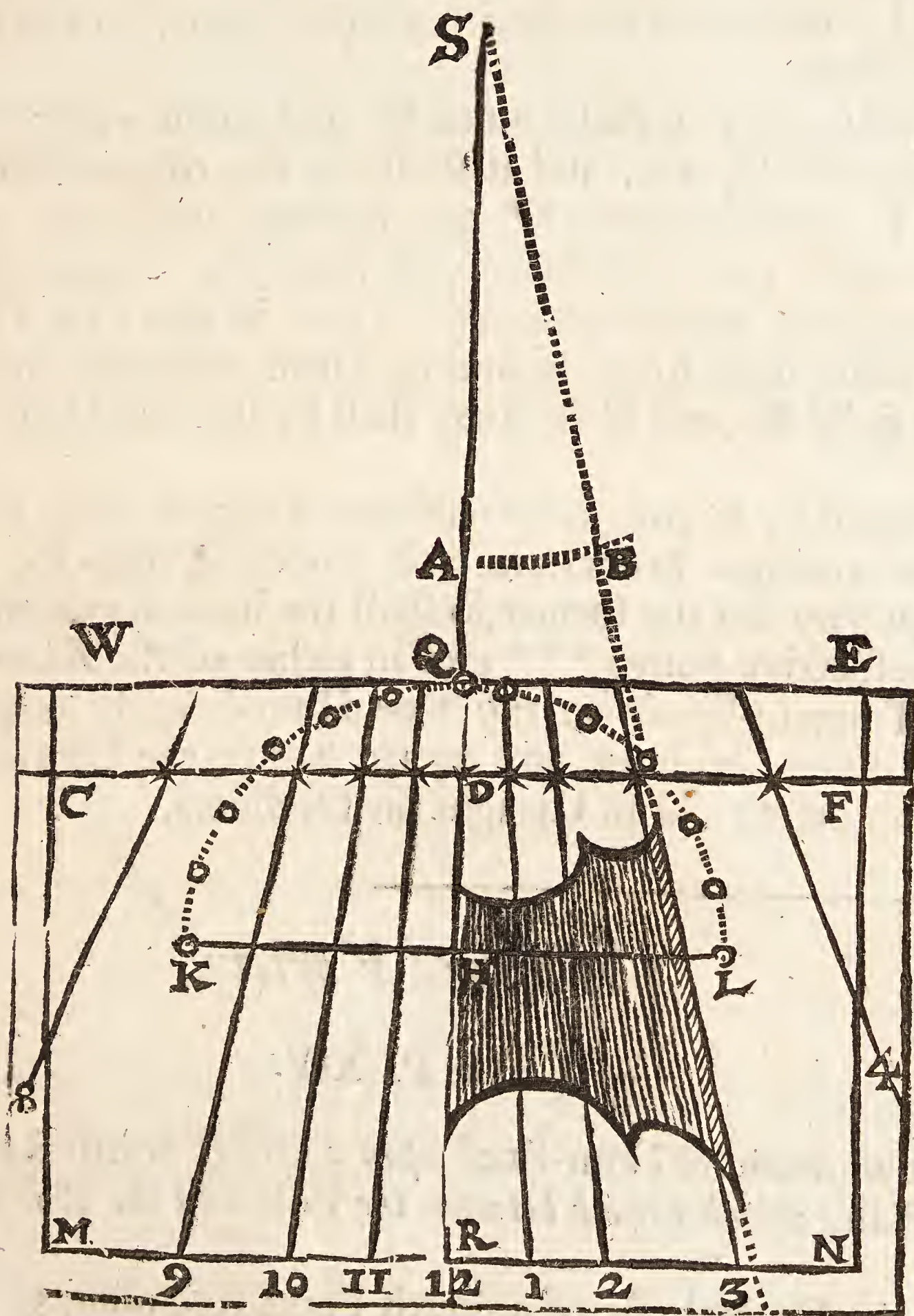
How to draw the Hour-lines upon the Plain.

In the Scheme following, draw, *First*, The right Line W Q E, for the *Horizontal*, and perpendicular thereunto, in the Line S Q R, for the *Meridian* and Hour-line of 12, which extend above the *Horizontal* Line to S.

Secondly, Upon S as a Centre, with 60 deg. of your Chord, describe a small Arch of a Circle, and upon it set
13 deg.

13 deg. 28 min. the height of the Pole above the Plain from A to B, and draw the Line S B for the Stile.

South Reclining 25 Degrees.



Thirdly, At any convenient distance, answerable to the largeness of your Plain, draw a Line parallel to W E, as the Line C D F.

Fourthly,

Fourthly, Set one Foot of your Compasses in D, and with the other, take the nearest distance to the Stile S B, which distance set upon the *Meridian* from D to H.

Fifthly, Upon the point H, (your Compasses opened to 60 deg. of your Line of Chords) describe the Semicircle K Q L, which divide into 12 equal parts, in the points $\odot \odot \odot \&c.$

Sixthly, Lay a Ruler unto H, and upon every of the points $\odot \odot \odot, \&c.$ and it shall cut the *Æquinoctial* Line C D F, in the points $*** \&c.$ through which the Hour-lines must pass: Wherefore, if from the Centre S, and through the several points $*** \&c.$ in the Line C D F, you draw strait lines, bounding them between any two lines as W E, and M N, they shall be the true Hour-lines. Or,

Seventhly, If you draw another Tangent line, and describe another Semicircle, and divide it, and the other line, as you did the former, so shall the lines drawn through the respective points $*** \&c.$ in either of the *Æquinoctial* (or Tangent-lines) be the true Hour-lines belonging to your Plain, without any regard had to the Centre at all, as you before did in Upright far Decliners.

The Third Variety.

CHAP. XIV.

How to draw the Hour-lines upon a Direct South Reclining Plain, which passeth between the Pole and the Horizon.

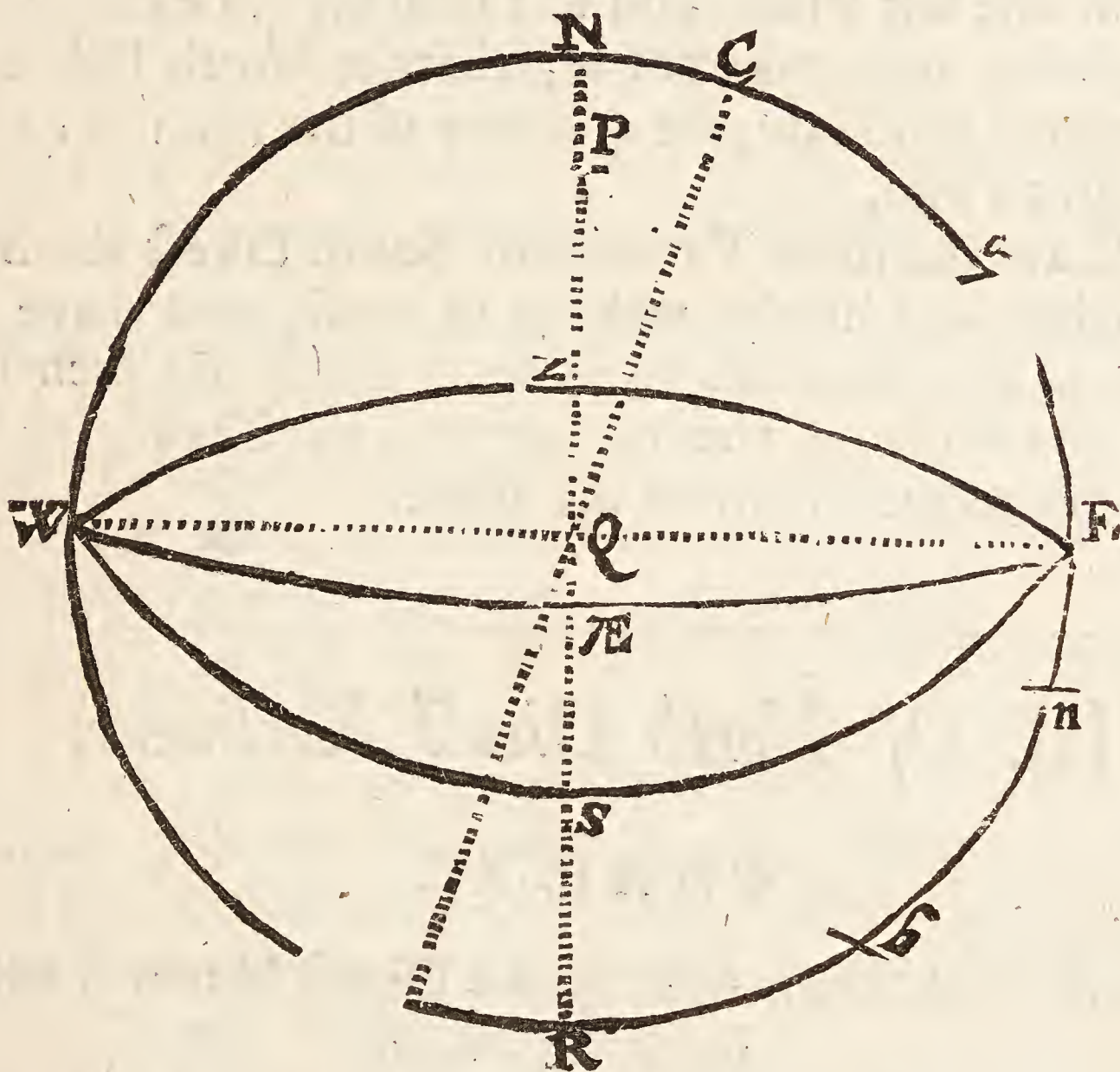
Let the Example be of a South Plain, Reclining 55 deg. in the Latitude of London, 51 deg. 32 min.

F*irst*, Draw the Circle W N E R, for your Reclining Plain, cross it with the two Diameters N Q R, the *Meridian*

Meridian, and W Q E, the Horizontal Line of the Plain.

Secondly, Take 55 deg. the Plains Reclination, out of your Line of Chords, and set that distance from N to *a*, and from E to *b*.

Thirdly, Lay a Ruler from W to *a*, it will cut the Meridian in Z, so is Z the Zenith of the place, through which, and the points W and E. draw the prime Vertical Circle W Z E.



Fourthly, Lay a Ruler from W to *b*, and it will cut the Meridian in S, the South point of the Horizon, through which, and the points W and E, the Horizon of the place W S E must be drawn.

Fifthly, The Pole being distant from the Zenith of the place 38 deg. 28 min. equal to the Complement of the Latitude, set 38 deg. 28 min. from *a* to *c*, and a Ruler laid from W to *c*, shall cut the Meridian in P the Pole of the World, and 90 deg. of your Line of Chords being set from

from *c* to *n*, and a Ruler laid from *W* to *n*, shall cut the Meridian in *Æ*, through which, and the points *W* and *E* must the *Æquinoctial* Circle be described: The Centre whereof, as also of the *Horizon* and prime Vertical Circles, are all in the Meridian *N Q R*, extended where need requires, and how these Centres are to be found, is shewed already.

Sixthly, For the drawing of the Hour-lines, they must be drawn as in the Erect Direct South Plain, or as was directed in the last Plain, and so I shall say no more of them in this place; only take notice, that the North Pole is elevated above this Plain, the quantity of the Arch *N c*, which is 16 deg. 32 min.

These are the three Varieties of South Direct Reclining Plains, and in the making of these, you have also made the opposite Incliners as much, for each Plain hath two faces, the one open to the *Zenith*, and the other to the *Nadir* of the place.

III. Of North Direct Recliners.

CHAP. XV.

How to draw the Hour-lines upon a Direct North Reclining Inclining Plain.

AS in South Reclining Plains there were Three Varieties, so also are there as many in the North Recliners; For,

I. The North Plain may so Recline, that it may pass through the Meridian, just at the intersection of the Meridian with the *Æquinoctial*, the plain it self lying in the *Æquinoctial* Circle, and the poles thereof in the Poles of the World, and so it is called *A Polar Plain*. Or,

2. The

2. The Plain may so Recline, that it may cut the Meridian between the *Zenith* and the *Æquinoctial*. Or,

3. It may Recline so far, as to cut the Meridian between the *Æquinoctial* and the *Horizon*.

Examples of these three Varieties of North Reclining Plains follow.

The First Variety.

CHAP. XVI.

How to draw the Hour-lines upon a Direct Polar Plain, which Reclineth just to the Æquinoctial.

Example of a North Plain, Reclining 51 deg. 32 min. equal to the Latitude of the Place viz. London.

First, Describe the Circle E Æ W R, for your Plain, cross it with the Diameters Æ Q R, for the Meridian, and W Q E for the prime Vertical Circle.

Secondly, Set 51 deg. 32 min. the Reclination of the Plain (which in this Example is also equal to the Latitude of the place) from Æ to *a*, and also from W to *b*.

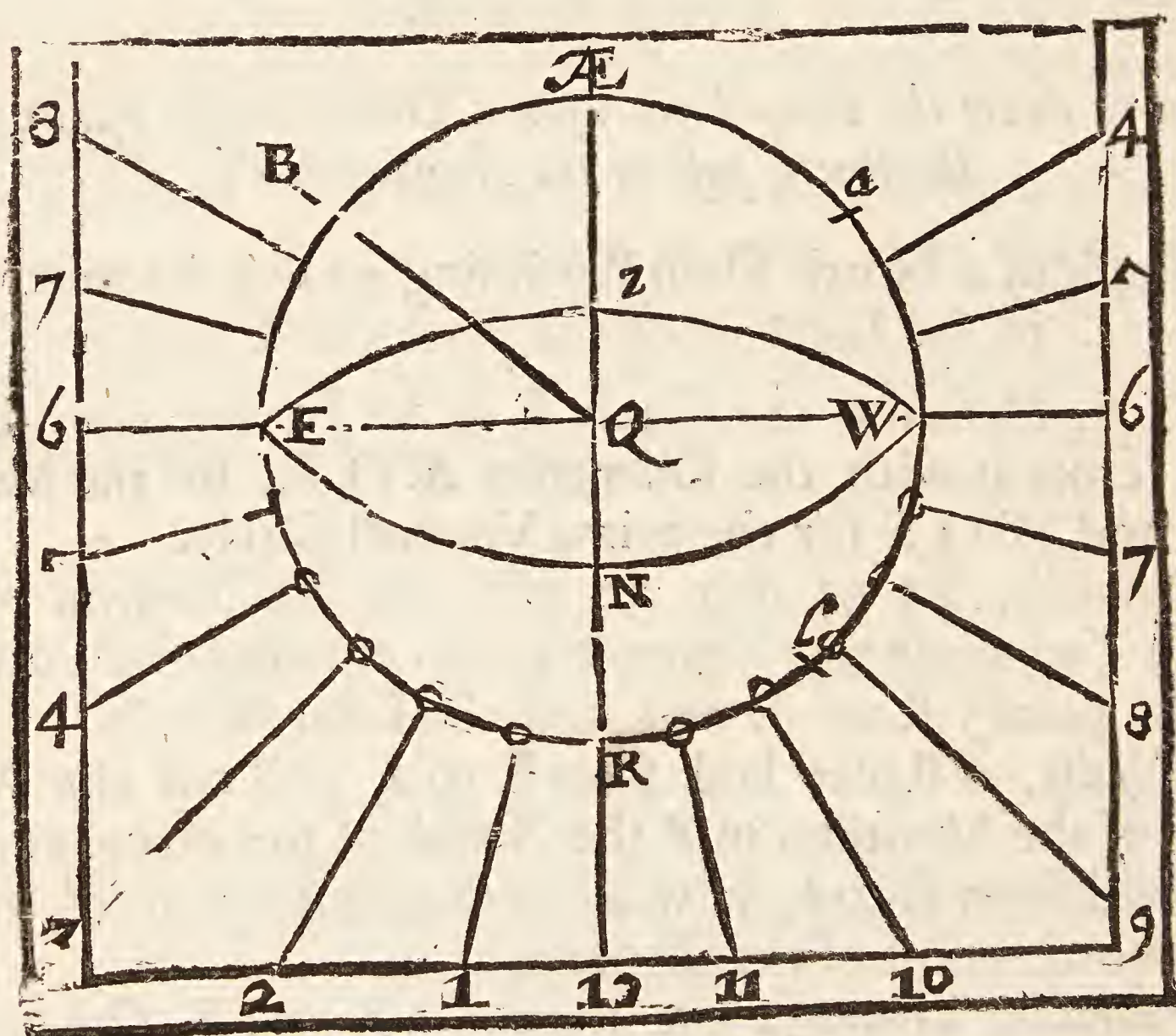
Thirdly, A Ruler laid from E to *a*, will cut the North part of the Meridian in Z the *Zenith* of the place, and being laid from E to *b*, it will cut the Meridian in N, so is N the North point of the Horizon.

Fourthly, Through the points W Z and E (by former directions) draw the prime Vertical Circle, or Azimuth of East or West, W Z E. And also through W N and E, draw the Horizontal Circle W N E.

Fifthly, Because the Pole of the World is always removed from the *Zenith* of the place, so much as is the Complement of the Latitude (in this Example 38 deg. 28 min.) Set 38 deg. 28 min. from *a* (the point in the Plain, which found the Zenith point Z,) Northward of the Zenith, and the Compass-point will fall in W, the West point of the

Horizon; so that if a Ruler were laid from W to E, it would cut the Meridian in Q, for the Pole of the World, which is already the Centre of the plain, so that the pole of the World, and the pole of the plain fall both in one point, and the pole Q is elevated above the plain 90 deg. viz. the quantity of the *Meridian Line* Æ Q, or rather the Arch Æ W, which is the measure thereof.

A Direct Polar Dial South.



Sixthly, To draw the Hours upon this Plain, it is easiest of all others, for if you divide the Semicircle E R W, into 12 equal parts in the points $\odot \odot \odot \&c.$ and through those points draw straight lines from the Centre Q, they shall be the true Hour-lines belonging to this *Polar Plain*.

And this Plain, by reason of its North Reclination, is, in Summer, capable of receiving all the hours from Sun rising to

to Sun setting, and therefore the Hour-lines of 4 and 5 in the morning, and of 7 and 8 at night must be drawn through the Centre, as you did in the Vertical or Horizontal Dial, and as you see here done in this Figure.

The Stile of this Dial must be a strait Pin or Wire, set perpendicular upon the Plain, from the Centre Q, and of any length. And this for the First Variety of North Recliners.

The South Inclining Plain opposite to this, is directly the same, only the forenoon hours in this must be the Afternoon hours in that, and the hours of 4 and 5 in the morning, and of 7 and 8 in the Evening must be omitted.

The Second Variety.

CHAP. XVII.

How to draw the Hour-lines upon a North Reclining Plain, which intersects the Meridian between the Zenith and the Æquinoctial.

Let the Example be of a North Plain, Reclining 25 deg.

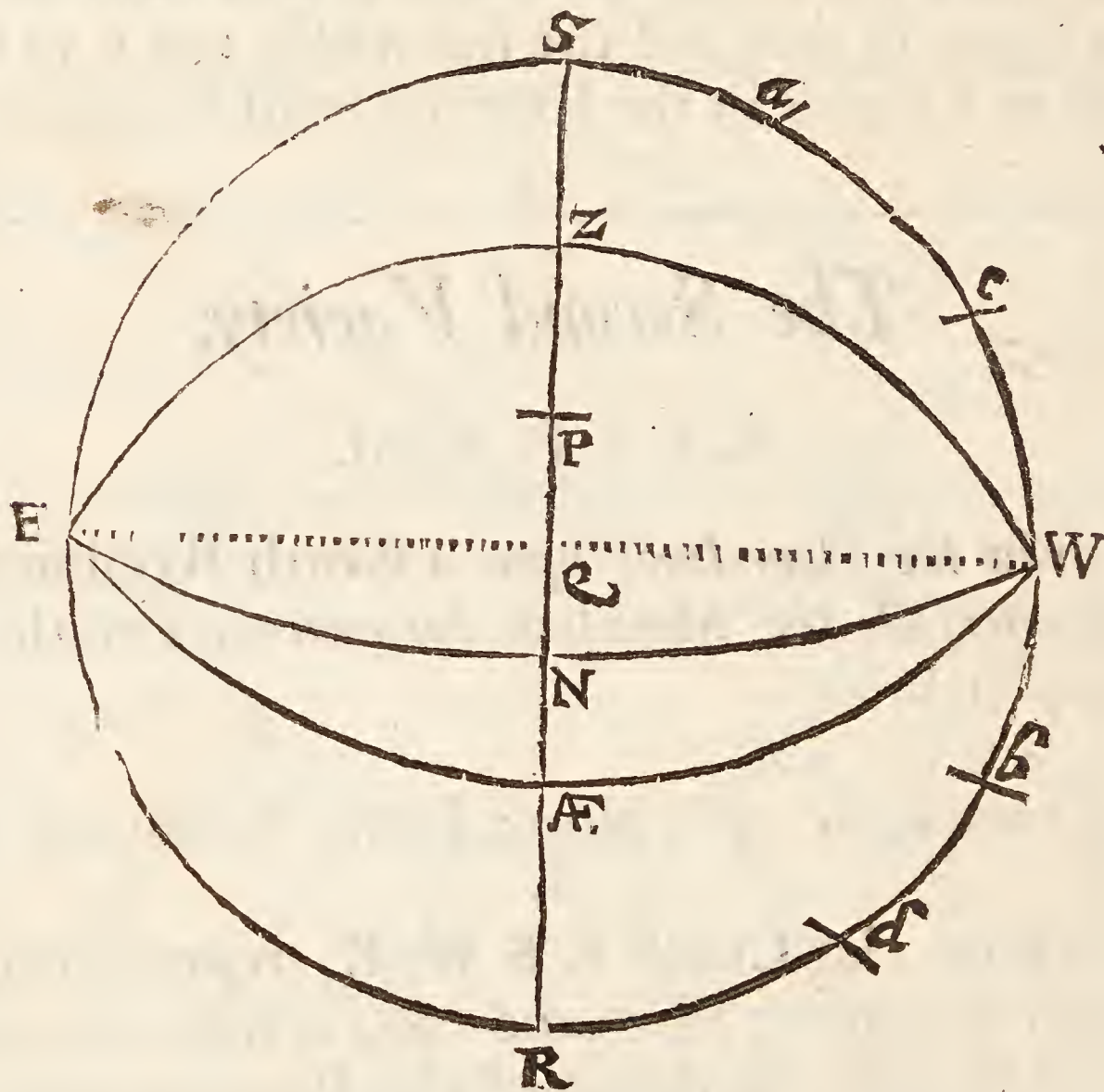
First, Draw the Circle E S W R, representing your North Reclining Plain, and cross it with the two Diameters S Q R, the Meridian of the Place, and E Q W, the Horizontal Line of the Plain.

Secondly, Set the Reclination of the Plain 25 deg. from S to *a*, and from W to *b*.

Thirdly, Lay a Ruler from E to *a*, it will cut the Meridian in Z the Zenith. And a Ruler laid from E to *b*, will cut the Meridian in N the North point of the Horizon: so have you three points E Z and W, whereby to draw the prime Vertical Circle E Z W, and three points also, viz. E N and W, whereby to draw the Horizon E N W.

Fourthly,

Fourthly, Because the *Æquinoctial* is always 90 deg. distant from either of the Poles, set 90 deg. upon your Plain, from *c* to *d*. Then laying a Ruler to *E* and *d*, it will cut the *Meridian* in *Æ*, so is *Æ* the point of the intersection of the *Æquinoctial*, with the North part of the *Meridian*; wherefore through the points *E* *Æ* *W*, describe the *Æquinoctial Circle*; the Centre whereof, as also of the *Horizon*, and prime *Vertical Circle*, will fall in the *Meridian* *S Q R*, extended where need requires.



Fifthly, The *Horizon*, *Æquinoctial* and *Pole*, being thus seated in their true positions upon the Plain; the thing required in this Dial, is, *The height of the Pole above the Plain*, which may be found in this manner. ----- Lay a Ruler from *E* to *P*, and it will cut the Plain in *c*, the distance *S c*, measured upon your *Line of Chords*, will contain 63 deg. 28 min. which is the height of the pole above the *Reclining Plain*.

Lastly, For the drawing of the Hours, that is done the same

same way as in the Erect Direct South Plain, only here the Stile must be elevated above the *Meridian* line 63 deg. 28 m. whereas there it was only 38 deg. 28 min. the Complement of the Latitude. The North Pole is elevated above this Plain, and the Hours that the Plain is capable to receive, are 4, 5, 6, 7, 8, and 9 in the Morning, and 3, 4, 5, 6, 7, and 8 at Night.

The height of the Pole (or Stile) above this Plain may be found by adding the Complement of the Latitude 38 deg. 28 min. and 25 deg. the Reclination together, the sum whereof is 63 deg. 28 min. the height of the Stile, as before.

The Third Variety.

CHAP. XVIII.

How to draw the Hour-lines upon a Direct North Reclining Plain, which intersects the Meridian between the Æquinoctial and the Horizon.

Let the Example be of a Direct North Plain, Reclining 70 deg. in the Latitude of *London* 51 deg. 32 min.

First, Draw the Circle E S W R, representing your North Reclining Plain, and cross it with the two Diameters S Q R, for the *Meridian* of the Place, and with E Q W, the Horizontal Line of the Plain.

Secondly, Set the Reclination of the plain 70 deg. from S to *a*, and from W to *b*.

Thirdly, Lay a Ruler to E and *a*, it will cut the Meridian in Z the *Zenith*, through which, and the points E and W, draw the prime Vertical Circle E Z W. — Also, lay a Ruler from E to *b*, it will cut the *Meridian* in N, the intersection

tersection of the *Meridian* with the North part of the Horizon, now through the points E N and W, describe the Horizon of the place E N W.

Fourthly, Forasmuch as the Pole is distant from the Zenith of the place 38 deg. 28 min. (equal to the Complement of the Latitude) set 38 deg. 28 min. from *a*, the point which gave the Pole *P* to *c*, and lay a Ruler from E to *c*, so shall it cross the Meridian in *P*, the Pole of the World.

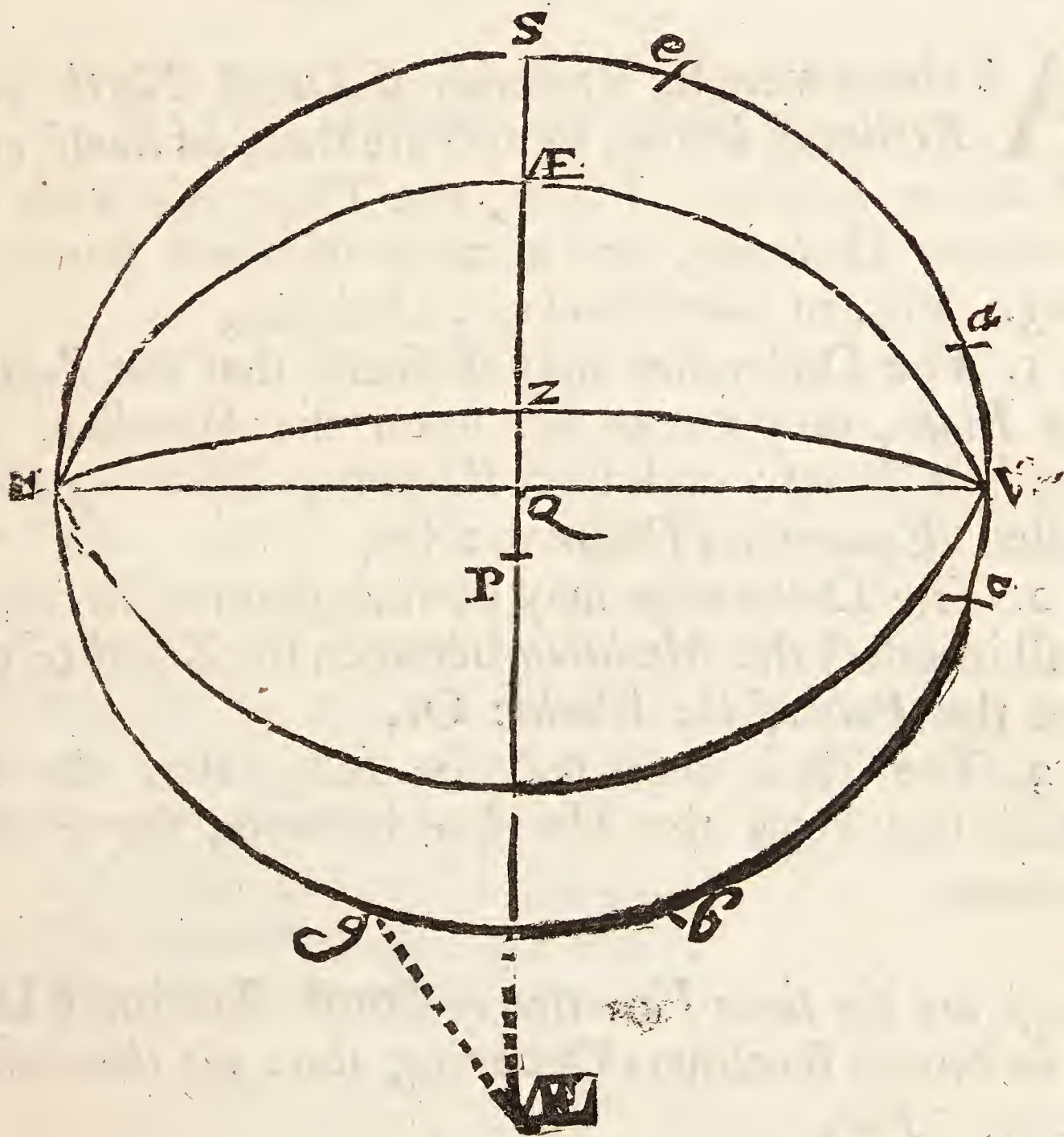
Fifthly, Because the *Æquinoctial* is in all places situate 90 deg. from either Pole. Take 90 deg. in your Compasses, and set them off from *c*, (the point which gave the Pole *P*) both ways, to *e* above, and to *g* below. So a Ruler laid from E to *g*, will cut the *Meridian* (it being extended) in *Æ*, without the Plain, which shews that the North part of the *Æquinoctial* Circle lies below this Plain. Therefore, lay a Ruler from E to *e*, and it will cross the *Meridian* in *Æ* above, within the plain. So is *Æ* the point where the Meridian, and the South point of the *Æquinoctial* will intersect, and through that point, and the points E and W, must the *Æquinoctial* E *Æ* W, be drawn.

Sixthly, the Horizon, Pole and *Æquinoctial*, being thus projected, the thing required in this plain, is, *The height of the Pole above it, viz.* P R, which may be found in this manner. — Lay a Ruler from E to *P*, and it will cut the plain in *c*, the distance from R to *c* measured upon the Chord, will be 71 deg. 32 min. which is the height of the pole above this Reclining plain. — Or the height of the pole above the plain may be found, by adding the plains Reclination 70 deg. to 38 deg. 28 min. the Complement of the Latitude, the Summ whereof is 108 deg. 28 min. which taken from 180 deg. the remainder will be 71 deg. 32 min. as before.

Lastly, For the drawing of the Hour-lines, they are done in all respects as those before in South Erect Plains, only in this make the Elevation of the Stile 71 deg. 32 min. as you find it by your projection.

Your

Your Hour-lines being drawn, erect the Stile 71 deg. 32 min. above the Meridian or Substile, letting it point up to the North Pole, because that pole above this plain is so much elevated, and being this Plain is but 20 deg. raised above the Horizon, *viz.* the Complement of its Reclination, the Plain is capable to receive all the hours from 4 in the morning, to 8 at night, and therefore the hours of 4 and 5 in the morning, and 7 and 8 in the evening, must be drawn through the Centre, as was done in the *Vertical* or *Horizontal Dial*.



And thus have you had Examples of all the Varieties,
both of *East, West, North, and South Reclining Plains*;
and no other can possibly fall out in any place what-
soever.

soever. The *Inclining Plains* are the same with the *Recliners* opposite to them; and must be drawn in the same manner, as hath been (in some measure) heretofore hinted, and shall be more at large discoursed of hereafter, when I have done with *Declining Reclining Plains*, of which I come now to treat.

IV. Of Declining Reclining Plains.

CHAP. XIX.

AS there were six Varieties of *Direct North and South Reclining Plains*, so also are there of *South and North Declining Reclining Plains*, viz. Three Varieties of *South Recliners Declining*, and as many of *North Recliners Declining*. For, in *South Recliners Declining*,

1. The *Declination* may be such, that the *South Reclining Plain*, may cut or fall upon the *Meridian*, just upon the *Pole Point*; and such *Reclining Declining Plains*, are called *Æquinoctial Decliners*: Or,

2. The *Declination* may be such, that the *Reclining Plain* shall intersect the *Meridian* between the *Zenith* of the place, and the *Pole of the World*: Or,

3. The *Declination* may be such, that the *Reclining Plain* shall cross the *Meridian* between the *Pole* and the *Horizon*.

These are the three Varieties of *South Recliners Declining*. In *North Recliners Declining* there are three other Varieties. For,

1. The *Declination* may be such, that the *North Reclining Plain* may cross the *Meridian* in the point where the *Æquinoctial* intersects the *Meridian*. And then such Plains are

are called *Polar Declining Plains*, because the Poles of them lie in the *Axis* of the *World*, and the *Substile* in such Plains, will be always perpendicular to the *Meridian* of the place. Or,

2. The *Declination* may be such, that the *Reclining Plain* may intersect the *Meridian*, between the *Zenith* and the *Æquinoctial*. Or,

3. The *Declination* may cause, that the *Reclining Plain* may fall upon the *Meridian*, between the *Æquinoctial* and the *Horizon*.

Examples of all these Varieties follow.

I. Of South Recliners.

The First Variety.

CHAP. XX.

How to draw the Hour-lines upon a South Reclining Declining Plain, which cutteth the Meridian in the Pole Point.

IN Declining Reclining Dials, before the Hour-lines can be drawn, Three things must be given, and Four things found; the things given are,

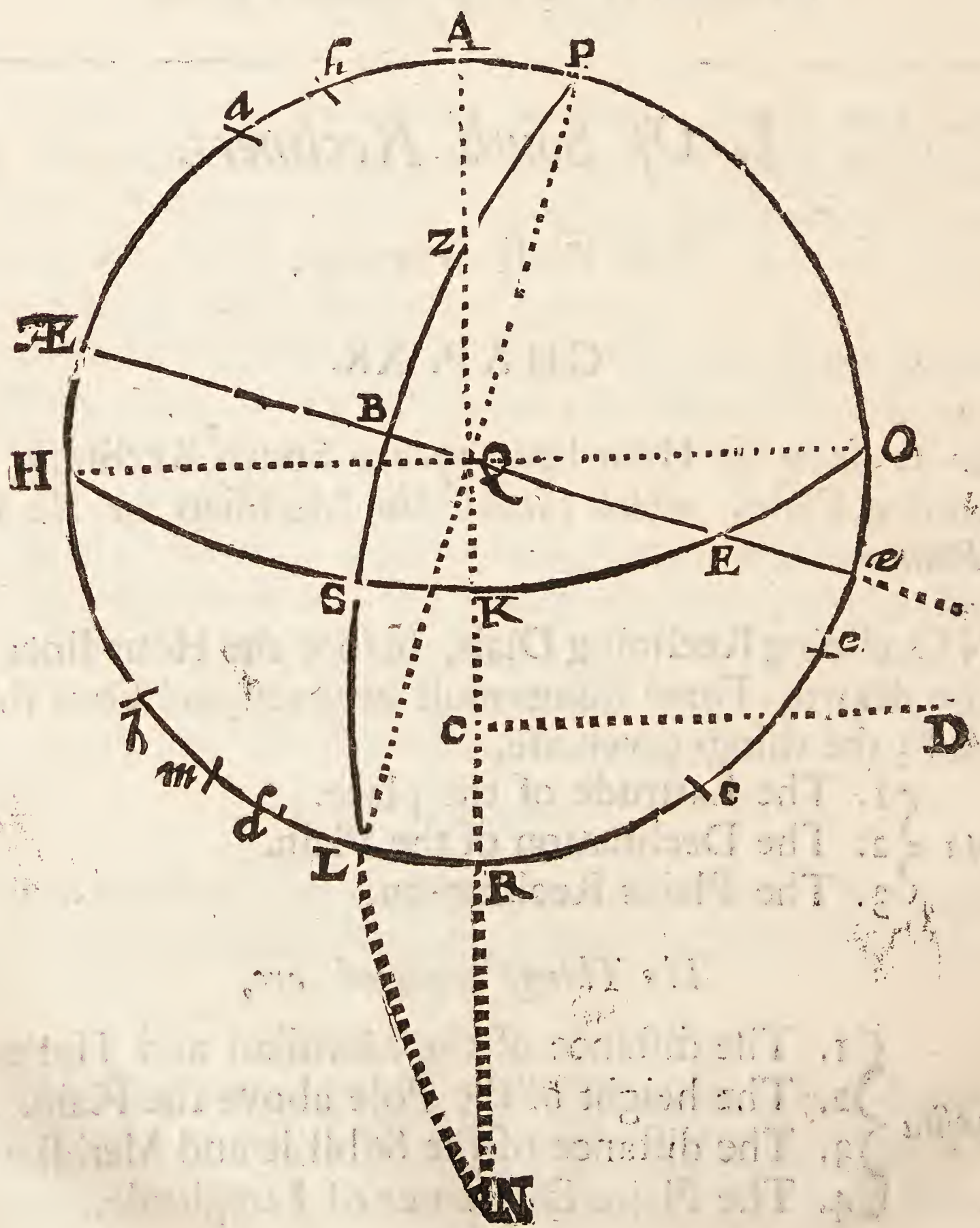
Data { 1. The Latitude of the place.
2. The Declination of the Plain.
3. The Plains Reclination.

The Things required are,

Quæsitæ { 1. The distance of the Meridian and Horizon.
2. The height of the Pole above the Plain.
3. The distance of the Substile and Meridian.
4. The Plains Difference of Longitude.

Let the Example be of a South Plain Declining East, 30 d. and Reclining 34 deg. 32 min. in the Latitude of London, 51 deg. 32 min.

First, Draw the Circle H A O R, and cross it with the two Diameters H O, the Horizontal Line of the Plain, and A Q R, the perpendicular Line of the plain, crossing each other at Right Angles in Q the Centre of the Plain.



Secondly,

Secondly, Because the Plain Reclined 34 deg. 34. min. Take 34 deg. 34 min. from your Line of Chords, and set them upon your plain from A to *a*, from H to *b*, and from R to *c*.

Thirdly, Lay a Ruler from O to *a*, and it will cut the perpendicular Line of the Plain in Z the Zenith of the place. Also a Ruler laid from O to *b*, will cut the plains perpendicular in K, the intersection of the Horizon of the place, with the Plains perpendicular. And a Ruler laid from O to *c*, will cut the perpendicular of the plain A R (it being extended) in N the Nadir point. Having found these points upon the perpendicular Line of the Plain,

Fourthly, Through the points H K O, draw the Horizon of the place. And,

Fifthly, Because the Plain declines 30 deg. Eastward, take 30 deg. out of your Chord, and set them from R to *d*, and from O to *e*; and laying a Ruler from Z the Zenith to *e*, it will cross the Horizon in E, the East point thereof, and the Ruler laid from Z to *d*, will cross the Horizon in S the South point thereof, so have you found three points, viz. Z N and S, through which you may draw the Meridian, whose Centre you may find, as hath been before taught: Or in this manner;

Divide the space between Z and N in two equal parts in C, and through C draw the line C D parallel to Q O, extending it, as you shall have occasion. Also from Q, through E draw another Right Line Q E, extending it, as occasion shall offer; the point of those two lines intersection, is the Centre of the Meridian.

Which being drawn,

Sixthly, Lay a Ruler from E the East point of the Horizon to Z the Zenith, and it will cut the Plain in *b*. And, because the Pole of the World is distant from the Zenith 38 deg. 28 min. equal to the Complement of the Latitude, set 38 deg. 28 min. from *b* upon the Plain, and it will fall just upon P, which is the point of the plains intersection with the Meridian, which demonstrates the pole to have no elevation above the plain, and so the plain to be *Æquinoctial Declining*.

Seventhly,

Seventhly, Draw the Line P Q L for the Axis of the World, and, because the *Æquinoctial* Circle is in all parts distant from either Pole 90 deg. set 90 deg. from P or L, to *Æ*; and through Q, draw the Line *Æ* Q *æ*, for the *Æquinoctial* Circle, which is here a strait Line, and being extended, would pass through the Centre of the Meridian, and also through the East and West points of the Horizon, as it ought to do.

The Scheme being thus projected, the four Requisites from it are easily obtained. For,

1. *To find the distance of the Meridian, and the Horizon* O P. The Arch O P measured upon your Line of Chords will contain 71 d. 53 min. the distance required.
2. *The height of the Pole above the Plain* (the point P) 00 deg 00 min. therefore it is an *Æquinoctial* Declining Plain.
3. *The distance of the Substile and the Meridian*, the point P also. Therefore that, as also all the hours, must be parallel to the Substile.
4. *To find the Plains difference of Longitude*, Q P B. Lay a Ruler from P to B, and it will cut the plain in *m*, the distance L *m* measured upon your Chord, is the plains difference of Longitude 24 deg. 19 min.

These Requisites being thus found, I will now shew.

How the Hour-lines are to be drawn upon the Plain.

First, Draw a Line as B A C for the Horizontal Line of your plain, and upon any convenient point therein, as upon A, with 60 deg. or the Radius of your Line of Chords, describe the Semicircle B D C.

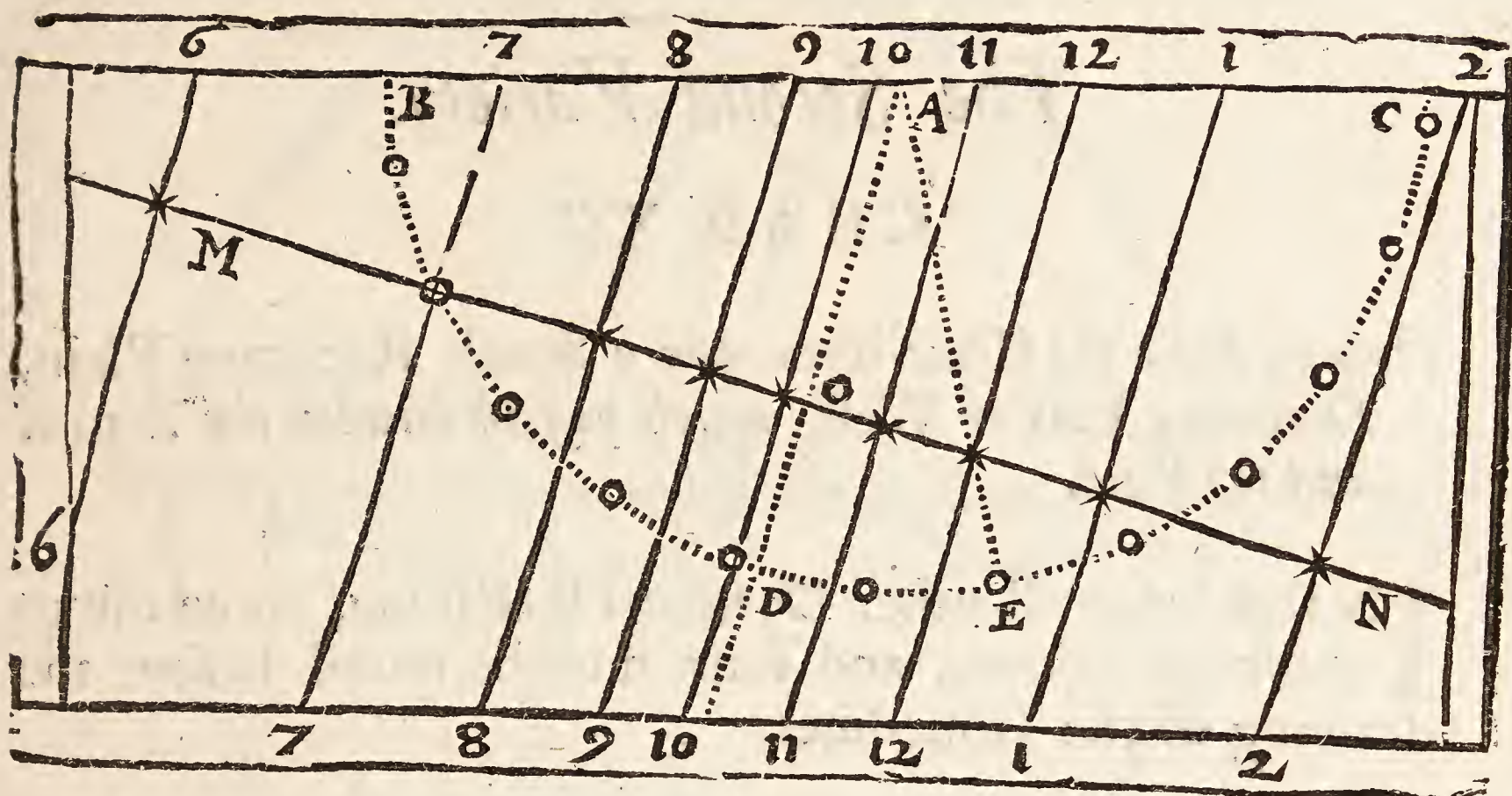
Secondly, From your Line of Chords take 71 deg. 53 m. the distance of the Meridian and Horizon, and set them from B to D, and draw the Line A D for the Substile.

Thirdly Take 24 deg. 19 min. the plains difference of Longitude, and set that distance from D to E, and draw the line A E.

Fourthly,

Fourthly, Divide the Semicircle B D C into 12 equal parts at the points $\odot \odot \odot \&c.$ beginning the division at the point E.

A South Plain Declining East 30 d. Reclining 34 d. 32 m.



Fifthly, Through the point O, (or any other point taken at all adventures in the Substilar Line) draw a Line M O N at right Angles (or perpendicular) to the Substilar, representing the Aequinoctial.

Sixthly, Lay a Ruler from A, and every of the points $\odot \odot \odot \&c.$ in the Semicircle, and it will cross the Aequinoctial in the points $*** \&c.$

Lastly, If through these points $*** \&c.$ you draw right lines parallel to the Substilar, they shall be the true Hour-lines belonging to your plain, the hour-line of 12 being that where you began to divide your Semicircle, that is, at the mark (or $*$) which was made from the point E.

For the Stile of this Dial, it may be either a strait pin or Wire, of the just length of the line A O, erected perpendicularly upon some point of the Substile (as at A or O) the very top of the shadow thereof giving the hour among the Hour-lines upon the Dial.

Or else the Stile may be a Plate of Brass or Iron of the breadth of A O, set perpendicular to the Plain, upon the Substilar Line A O D, the shadow of whose upper edge shall give the true hour of the day.

The Second Variety.

CHAP. XXI.

How to draw the Hour-lines upon a South Reclining Plain, Declining East or West, which passeth between the Zenith and the Pole.

IN this, as in all other Decliners Reclining, three things must be known, and four must be found before the drawing of the Hour-lines.

Let the Example be a South Reclining Plain, Declining East 30 deg. and Reclining 20 deg. in the Latitude of 51 deg. 32 min. London.

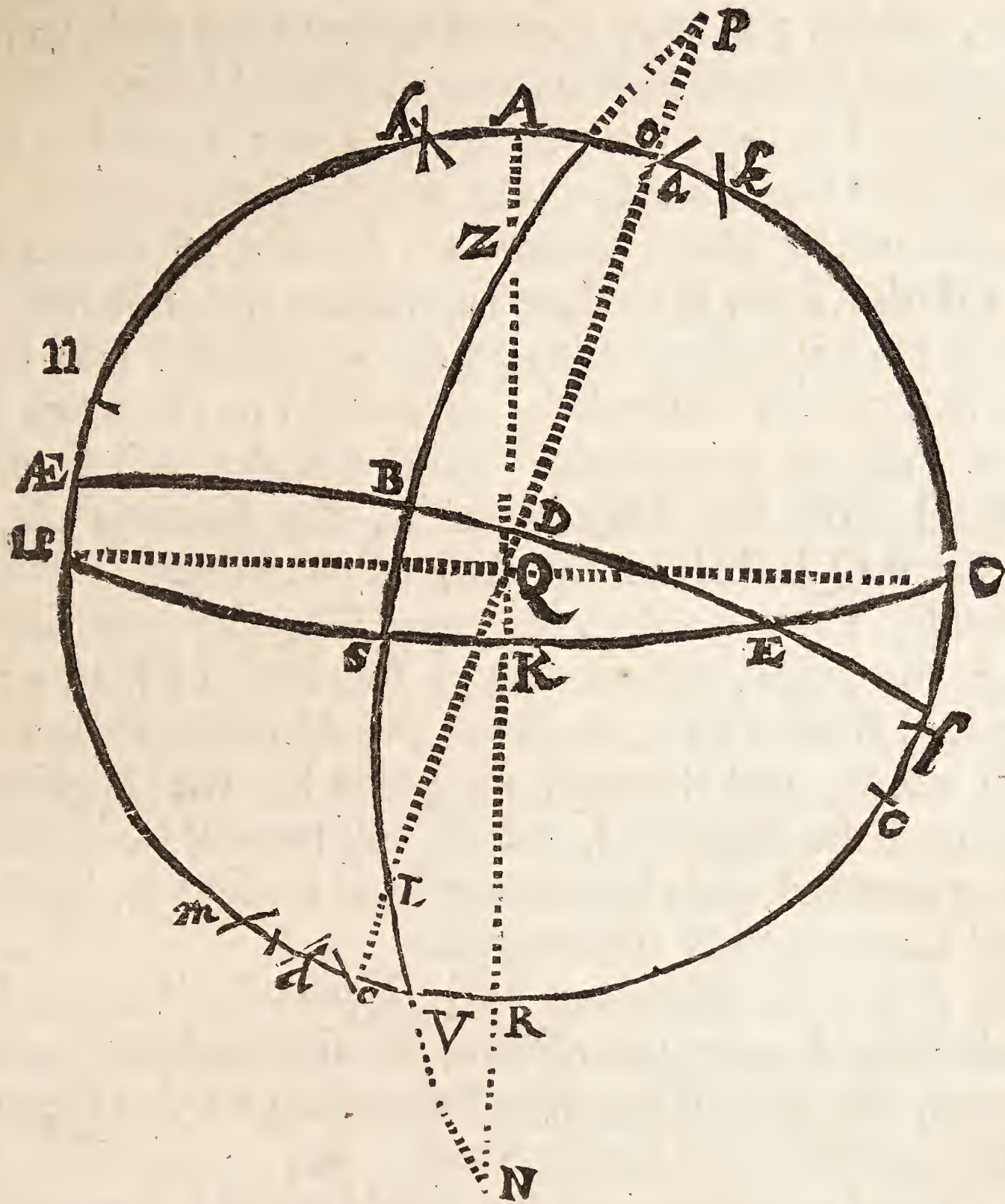
Data	{	1. Latitude of the place	51	32
		2. Declination South East	30	00
		3. Reclining South	20	00

<i>Quæsitæ</i>	{	1. The distance of the Meridian and Horizon.
		2. The height of the Pole above the Plain.
		3. The distance of the Substile and the Meridian.
		4. The Plains difference of Longitude.

First, Describe the Circle H A O R, representing your Reclining Declining Plain, and cross it at right Angles, with the two Diameters A R, for the perpendicular, and H O for the Horizontal Line of the Plain.

Secondly,

Secondly, Take 20 deg. the plains Reclination, out of your Chord, and set them from A to *a*, from O to *b*, and from R to *c*.



Thirdly, A Ruler laid from H to *a*, will give you Z the Zenith, and laid from H to *b*, will give you K the intersection of the Horizon, with the perpendicular line of the Plain. And the Ruler laid from H to *c*, will give you N the Nadir, then through the points H, K and O, draw the Horizon H K O.

Fourthly, Take 30 deg. the Plains Declination out of your Line of Chords, and set them from R to *d* Westward, (because the plain declines Eastward) and also from O to *e*, so a Ruler being laid from Z to *e*, shall cut the Horizon in E, the

the East point thereof, and laid from *Z* to *d*, shall cut the Horizon in *S* the South point thereof. Thus have you three points *Z*, *S* and *N*, through which to draw the Meridian Circle, which you may extend without the plain to *P* and *N*, occasion sometimes requiring it should be so.

Fifthly, Forasmuch as the Pole of the World is always distant from the *Zenith*, equal to the Complement of the Latitude of the place, as here at *London* 38 deg. 28 min. Lay a Ruler from *E* to *Z*, and it will cut the plain in *h*, from whence set 38 deg. 28 min. to *k*. So a Ruler laid from *E* to *k*, will cut the *Meridian* (extended) in the point *P*, the North Pole of the World. And a Ruler laid from *P* to *Q*, shall cross the *Meridian* in *L*, the South Pole, and the Line *P Q L* shall be the Axis of the World.

Sixthly, Take 90 deg. of your Chords, and set them from *k* the point, which found the Pole at *P* to *n*: So a Ruler laid from *E* to *n*, shall cut the *Meridian* in *B*, through which point, and through the point *E*, the *Æquinoctial* Circle must be described, whose Centre will be in the Axis *P L* extended, and the manner how to find it, hath been several times already discovered.

The *Horizon*, *Meridian*, and *Æquinoctial* Circles being thus described upon your Plain, by their intersections, and distances, the four Requisites belonging to this Declining Reclining Plain may be obtained. As,

1. To find the distance of the *Meridian* and *Horizon* *H V*.

The distance *H V* upon the Plain, measured upon the Line of Chords, will contain 78 deg. 50 min. the distance of the *Meridian* and *Horizon*.

2. To find the height of the Pole or Stile above the Plain

L C. Set 90 deg. from *c* to *b*, then lay a Ruler from *b* to *L*, and it will cut the Plain at *m*, the distance from *c* to *m*, measured upon your Chords, will contain 13 d. 40 min. the height of the Pole or Stile above the Plain.

3. To find the distance of the *Substile* from the *Meridian*

V c,

Vc , measure the distance Vc upon the Line of Chords, and it will contain 7 deg. 30 min. the distance required.

4. To find the Plains difference of Longitude, BLD . Lay a Ruler from L to B , it will cut the Plain in b , so the distance bO measured upon the Line of Chords, will contain 28 deg. 52 min. the Plains difference of Longitude.

Thus are the four Requisites belonging to this Plain found, and in this Example, two things are very observable.

1. Whereas P the North Pole of the World, falls without the plain, and the point L , representing the South Pole falls within the plain, it denotes, that the South Pole must be elevated.
2. In respect that the Line or Arch Lc , which is the height of the Stile or pole above the plain, is but of small Quantity, viz. 13 deg. 40 min. it will from thence follow, that the *Æquinoctial's* Centre will be very remote, and that the Hour-lines near to the Substile will be very close, so that in small Dials their distances one from another will be insensible; and therefore you may save the labour of describing the *Æquinoctial* Circle, and be satisfied in finding of the point B , by which the plains difference of Longitude is found——For, in such cases as this, the *Plains difference of Longitude*, the *distance of the Meridian from the Horizon*, and of the *Substiles distance from the Meridian*, and the *height of the Pole above the Plain* being gained; you may proceed to draw the Dial as followeth, not much differing from the drawing of the Upright far declining Dial Chapter VIII.

How to draw the Hour-lines upon the Plain.

First, Draw a right Line ABC , for the *Horizontal Line*
N 2 of

Secondly, From D to E set 7 deg. 30 min. the distance of the Substile from the *Meridian*, the same way as you find it to lie in your projection, and draw the Line B E for the Substile. Also, upon the same Arch, set off 13 deg 40 m. the height of the Stile from E to F, and draw the line B F for the Stile. Which being but of small Elevation, *viz.* 13 deg. 40 min. ought to be augmented; and therefore (at any convenient distance (suitable to the bigness of your Dial-plain) draw a line as G H, parrallel to B F, for your augmented Stile or Axis.

Thirdly, Through any two points taken at adventure, in the Substilar line, as K and L, draw two right lines perpendicular, or at right Angles to the Substilar, as the Lines M K N, and O L P. Then from the point K, take the least distance to the augmented Stile G H, and set that distance upon the Substilar K to Q. Also from the point L, take the nearest distance to the augmented Stile G H, and set that distance upon the Substilar from L to R.

Fourthly, Upon the points Q and R, as upon two Centres, with 60 deg. of any of your Chords, describe two Semicircles (or other portions of Circles) and in either of them set 28 deg. 52 min. from V to T upon one of them, and from X to S upon the other.

Fifthly, Lay a Ruler from Q to T, and it will cut the Tangent Line in Y: Also lay a Ruler from R to S, it will cut the other Tangent line in Z, and a right line drawn through the points Y and Z, shall be the Hour-line of 12.

Sixthly, At the points S and T, begin to divide the several Semicircles in 12 equal parts or hours, by taking 15 d. of your Chord, and setting them from S and T both ways, at the points $\odot \odot \odot \&c.$ so many times as the plain will receive Hour-lines.

Seventhly, Lay a Ruler from the points Q and R, to every of the points $\odot \odot \odot \&c.$ in their respective Semicircles, and it will cross their several Tangent lines in the points * * * $\&c.$

Lastly,

Lastly, Through the points * * *, in both the Tangent lines, draw right lines, each to his correspondent, which the Hour-line of 12 will direct you how to do, and those shall be the true Hour-lines of your Plain.

For the Stile of this Dial, it may be either of Wire, or Plate, containing an Angle equal to the height of the Pole above the Plain, but it must be augmented answerable to the augmented Stile, as you see in the Figure, and must be set in its proper place upon the Substilar line, and also perpendicular or square to the Plain, and so is this Dial finished.

The Third Variety.

CHAP. XXII.

How to draw the Hour-lines upon a South Reclining Plain, Declining East or West, which intersects the Meridian between the Pole and the Horizon.

L Et the Example for this third and last Variety of South Declining Reclining Plains, be of a *South Plain Declining Eastward 30 deg. and Reclining 55 deg. in the Latitude of 51 deg. 32 min. viz. London.*

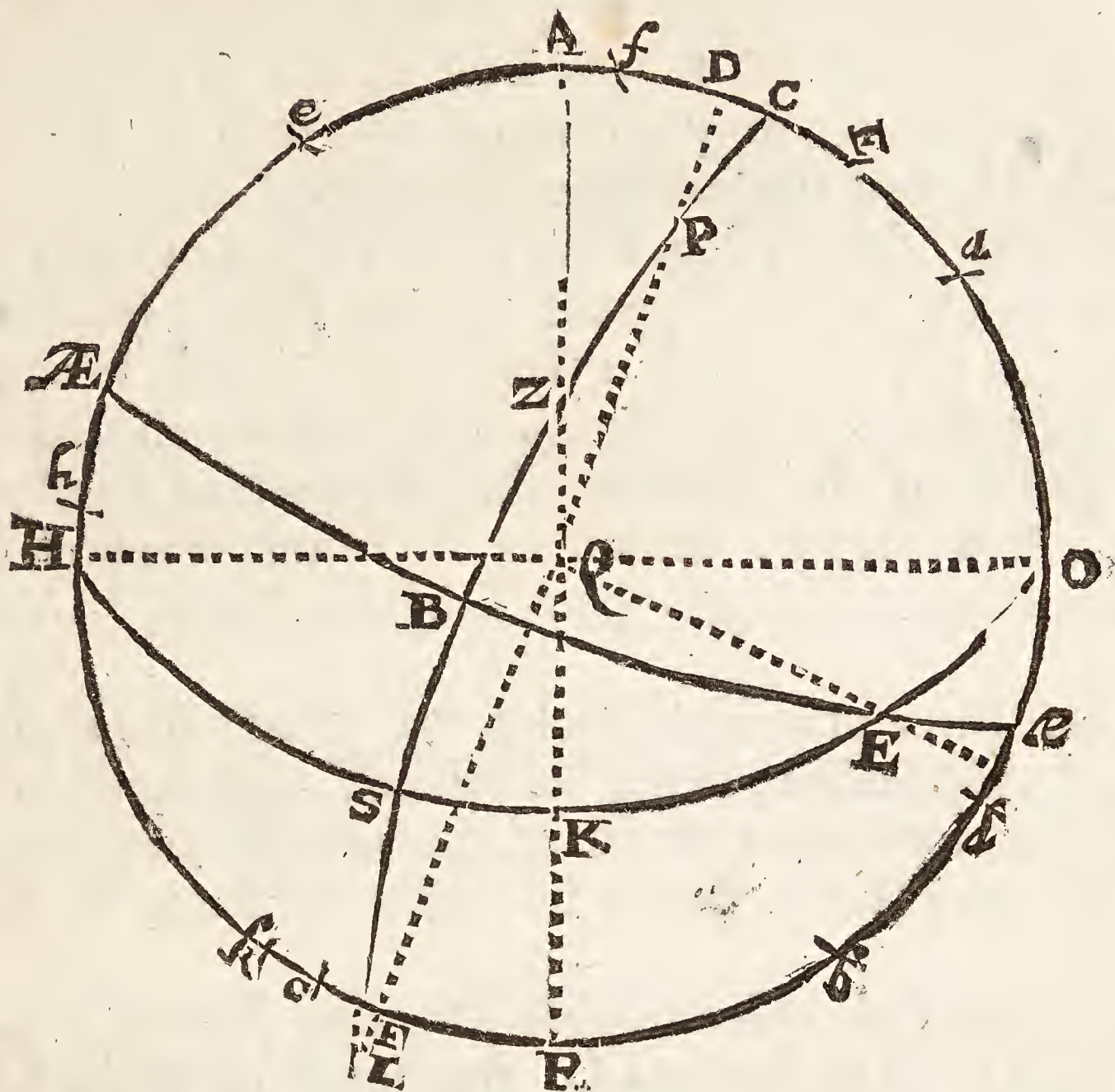
		deg.	min.
<i>Data</i>	The Latitude of the Place	51	32
	The Declination Eastward	30	00
	The Reclination	55	00

Quæsitæ { The distance of the *Meridian* from the *Horizon*.
 The height of the Pole or Stile above the Plain.
 The *Substiles* distance from the *Meridian*.
 The Plains difference of Longitude.

First,

First, Draw the Circle A H R O, for your Reclining Declining Plain, and cross it with the two Diameters A R the Vertical, and H O the *Horizontal* line of the Plain.

Secondly, set 55 deg. the Plains Reclination from A to *a*, and from O to *b*.



Thirdly, Lay a Ruler from H to *a*, and it will give you Z the Zenith, and laid from H to *b*, it will give you K, the point of the Horizons intersection with the Plains Vertical Line. So have you three points H K and O, through which to describe the Horizon of the place H K O.

Fourthly, Set 30 deg. the Plains Declination from R to c Westward, (because the Plain declines Eastward) and from O to d. So a Ruler laid from Z to c, shall give you S, the intersection of the *Meridian* with the South point of the *Horizon*. And the Ruler laid from Z to d, shall give you E the East point of the *Horizon*.

Fifthly, Having the Points S and Z, through them you may

may draw the *Meridian Circle* L S Z P, as hath been already several ways taught, the Centre whereof will fall in the Line Q E being extended.

Sixthly, Lay a Ruler from E to Z, and it will cut the Plain in e, from which point e, set 38 deg. 28 min. to f, and a Ruler being laid from E to f, shall give the point P, upon the *Meridian Circle*, for the Pole of the World. And a Right Line drawn from P through Q, shall be the Axis of the World, and the Substilar line of the Dial.

Seventhly, Set 90 deg. from f to h, (because the *Æquinoctial Circle* is in all places 90 deg. distant from either Pole, P or L.) So laying a Ruler from E to h, it will give you the point B in the *Meridian*, through which, and E, the East point of the *Horizon*, the *Æquinoctial Circle* must pass. And may be drawn as in former Examples, the Centre thereof being in the Axis of the World, P L extended.

These three principal Circles, viz. the *Horizon*, *Meridian* and *Æquinoctial*, being described, according to their true Situations upon the Plain, the same forementioned Requisites may from thence be easily deduced, as followeth.

1. To find the distance of the *Meridian* from the *Horizon* O C. The Arch O C, measured upon the Line of Chords, will contain 64 deg. 41 min. The *Substiles distance from the Meridian*.
2. To find the height of the Pole or Stile above the Plain P D. Set 90 deg. from D to æ, and lay a Ruler from æ to P, it will cut the Plain in m, the Arch D m measured on the Line of Chords, will contain 19 deg. 25 min. The height of the Stile.
3. To find the *Substile's distance from the Meridian* C D. This Arch measured, will contain 6 deg. 2 min. The distance of the *Substile from the Meridian*.
4. The Plains difference of Longitude B P Q. A Ruler laid from P to B, will cut the Plain in k. So the distance

F k

Fk measured, will be 17 deg. 38 min. *The Plains difference of Longitude.*

These requisites being thus found, you may proceed to draw the hour-lines in this as in other Plains. First, by laying a Ruler upon P the Pole of the World, to B , in the intersection of the *Meridian* and *Æquinoctial*, which will cut the Plain in k , at which point, begin to divide the Semicircle into 12 equal parts. And from Q , to each of them, lay a Ruler crossing the *Æquinoctial* Circle, and dividing that into 12 unequal parts, to which unequal parts of the *Æquinoctial*, a Ruler laid, it will divide the Plain into 12 other unequal parts, through which, and the Centre Q , right lines being drawn, they shall be the true hour-lines proper for the Plain.

But in this Example, the Elevation of the Pole or Stile above the Plain, being but of an indifferent Elevation, viz. 19 deg. 25 min. you may (if you please) draw the Hour-lines by one Tangent line, and the Centre, as was shewed in the Second Variety of Direct South Reclining Plains; and as here followeth.

How to draw the Hour-lines upon the Plain.

First, Upon your Plain, towards the bottom thereof (because the North Pole is here elevated) draw a right line AB , parallel to the *Horizon*, and assume A for the Centre of your Dial, upon which point, with 60 deg. of your Chord, describe an Arch of a Circle BE , upon which from B , set the distance of the *Meridian* and *Horizon*, 64 deg. 41 min. to C , and draw the line AC for the Hour-line of 12. Also, upon the same Arch from C to D , set 6 deg. 2 min. the distance of the Substile from the *Meridian*; and draw the line AD for the Substilar. Again, upon the same Arch, set off 19 deg. 25 min the height of the Stile from D to E , and draw the Line DE for the Axis of the Stile.

gin to divide it into 12 equal parts in the points $\odot \odot \odot \&c.$

Fifthly, Lay a Ruler from O the Centre of the Semicircle to the several points $\odot \odot \odot$ in the Semicircle, and the Ruler will cut the Tangent line in the points $* * *$ $\&c.$

Lastly, If from the Centre A, through these points $* * *$ $\&c.$ you draw right-lines, they shall be the proper Hour-lines belonging to your Plain.

For the Stile it may be either of Plate or Wire, elevated above the Substile to an Angle of 19 deg. 25 min. and set up perpendicularly upon the Substilar, as in all other Dials. And thus have I done with all the Varieties of South Declining Reclining Plains.

II. Of North Recliners.

The First Variety.

CHAP. XXIII.

How to draw the Hour-lines upon a North Reclining Plain, Declining East or West, which cutteth the Meridian at the Intersection thereof with the Æquinoctial.

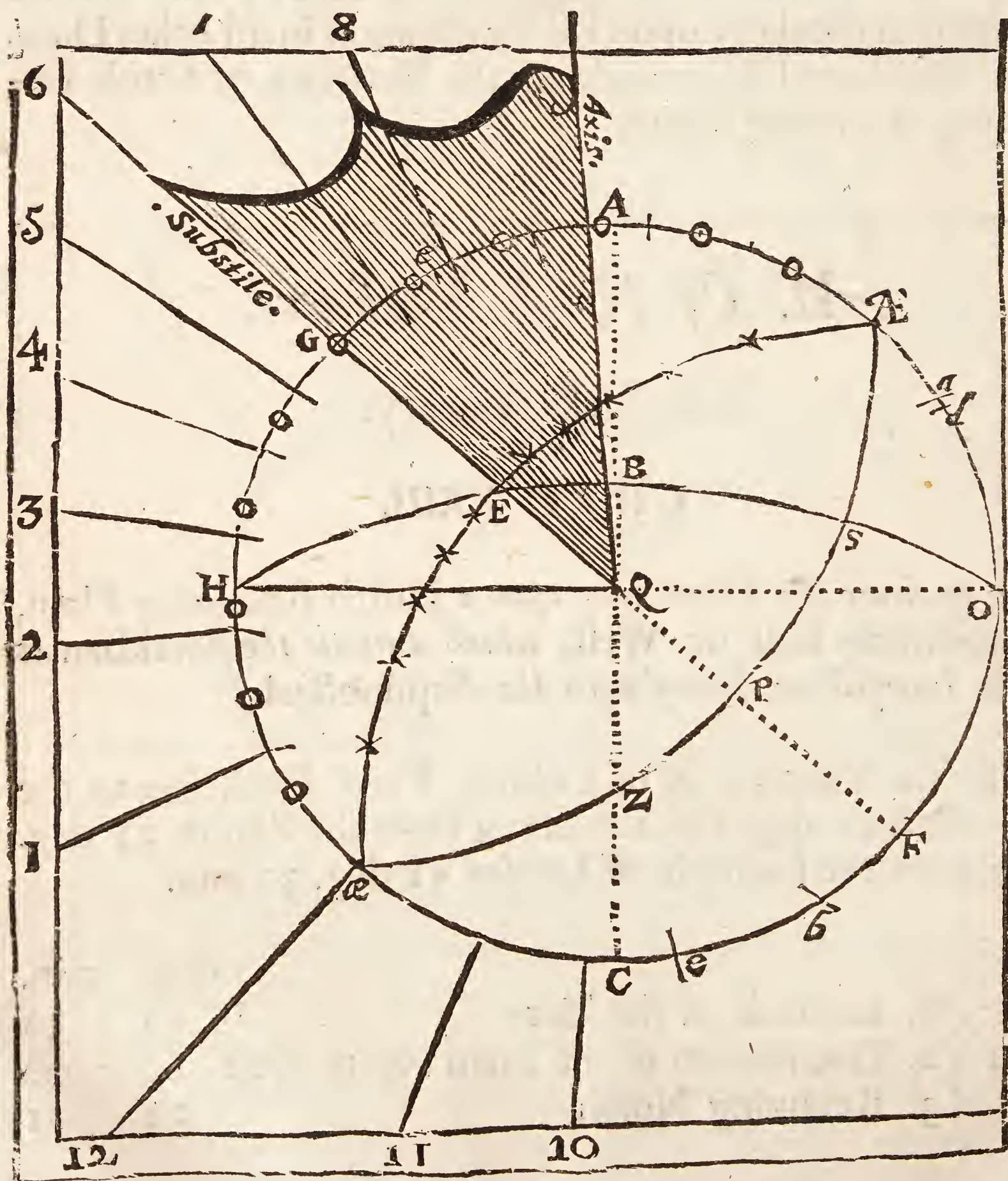
L Et the Example be of a North Plain Declining to the West 60 deg. and Reclining from the Zenith 32 deg. 11 min. in the Latitude of London 51 deg. 32 min.

		deg.	min.
Data	1. Latitude of the Place	51	32
	2. Declination of the Plain North West	60	00
	3. Reclining North	32	11

- Quæſita* { 1. The distance of the Meridian and Horizon.
 2. The height of the Pole or Stile above the Plain.
 3. The distance of the Substile and the Meridian.
 4. the Plains difference of Longitude.

North { Declining West
 Reclining

deg. min.
 60 00
 32 11



First, Describe the Circle A H C O, for the Declining Re-

Reclining Plain; cross it at right Angles with the two Diameters H O for the Horizontal, and A C for the Vertical line of the plain.

And here for Variety, more than for necessity, in these three following Examples of North Recliners Declining, I will (in the several Schemes) place the Zenith and pole down wards, because the Stile in all these Dials must point upwards, the North pole being always elevated, and in so doing, the Hour-lines, Stile and Substile will stand in the Scheme as they are to stand in the Dial. and the manner of Work will be the same as before. Wherefore,

Secondly, Set 32 deg. 11 min. the plains Reclination, from O to *a*, and from C to *b*. A Ruler laid from H to *a*, shall give you the point B, through which, and the points H and O, the Horizon H B O is to be described. And a Ruler laid from H to *b*, shall give you Z the Zenith point.

Thirdly, Set 60 deg. the plains Declination from A to *d*, a Ruler laid from Z the Zenith, to *d*, shall cut the Horizon in S the South point thereof. Thus have you two points Z and S, through which to draw the Meridian, whose Centre will be in the line Q E extended, and may be found as formerly is taught.

Fourthly, The Horizon and Meridian being thus drawn, lay a Ruler from E to Z, and it will cut the Plain in *e*, and seeing the pole is 38 deg. 28 min. distant from the Zenith, set 38 deg. 28 min. from *e* to F, and a Ruler laid from E to F, will cut the Meridian in P the Pole of the World, through which point P, and the Centre Q, draw the line P Q for the Axis of the World, and Substile of the Dial. And again, because the Æquinoctial is 90 deg. from the Pole, set 90 deg. from F, and they will reach just to Æ or *a* on either side, which are the very points that the plain cuts the Meridian in, and through which points, and the point E, in the Horizon, the Æquinoctial Circle must pass; whose Centre will always be in the the Axis of the World P Q extended.

The

The *Horizon*, *Meridian* and *Æquinoctial* being thus drawn, you may find the four Requisites in this manner.

1. To find the distance of the *Meridian* from the *Horizon* Æ O . The Arch Æ O measured by your Line of Chords, will be found to contain 47 deg. 18 min. which is the *Substiles* distance from the *Meridian*:
2. To find the height of the *Pole* or *Stile* above the *Plain* P F . A Ruler laid from æ to P , will cut the *Plain* in O , so the distance F O 42 deg. 52 min. is the height of the pole above the *Plain*.
3. The distance of the *Substile* from the *Meridian* æ G , which measured upon your Chord, will be found to contain just 90 deg.
4. The *Plains* difference of Longitude G P æ , or the Arch æ G , as before also 90 deg. just.

In this Scheme two things are remarkable.

1. The *Plains* cutting the *Meridian* in its intersection, with the *Æquinoctial*. And,
2. The *Axis* of the *World* passing through the East point of the *Horizon*, both which denote the *Plain* to be polar Declining, and the *Substile* to be the same with the *Hour-line* of 6. And the *Hour-line* of 12 at right Angles thereto, wherefore the *Hour-lines* may be drawn, as followeth.

To draw the Hour-lines upon the Plain.

First, Lay a Ruler from P to Æ , where the *Meridian* and *Æquinoctial* intersect, which is upon the plain at the very point Æ , wherefore there begin to divide the Semi-circle Æ G æ , into 12 equal parts at the points $\odot \odot \odot \&c.$

Secondly, Lay a Ruler to Q , and every of the points $\odot \odot \odot \&c.$ and it will cut the *Æquinoctial* in the points $*** \&c.$ dividing that into 12 unequal parts.

Thirdly, A Ruler laid to P , and the several points $*** \&c.$ in the *Æquinoctial*, will cut the plain in the marks $||| \&c.$

Lastly,

Lastly, A Ruler laid from Q to the several marks ||| &c. and strait lines drawn thereby, shall be the true Hour-lines fitting this polar Decling Plain.

For the Stile, it must be a Plate or Wire set upright upon the Substilar to an Angle of 42 deg. 52 min. and must point upwards to the North Pole.

The Second Variety.

CHAP. XXIV.

How to draw the Hour-lines upon a North Reclining Plain, Declining East or West, the Plain passing through the Meridian, between the Zenith and the Æquinoctial.

IN this (as in the former Examples) three things must be given, and four found, before the Hour-lines can be drawn.

		deg.	min.
<i>Data</i>	1. Latitude of the place	51	32
	2. The Declination of the Plain North W.	60	00
	3. The Plains Reclination	16	00

<i>Quæsitæ</i>	1. The distance of the Meridian from the Horizon.
	2. The height of the Pole or Stile above the Plain.
	3. The Substile distance from the Meridian.
	4. The Plains difference of Longitude.

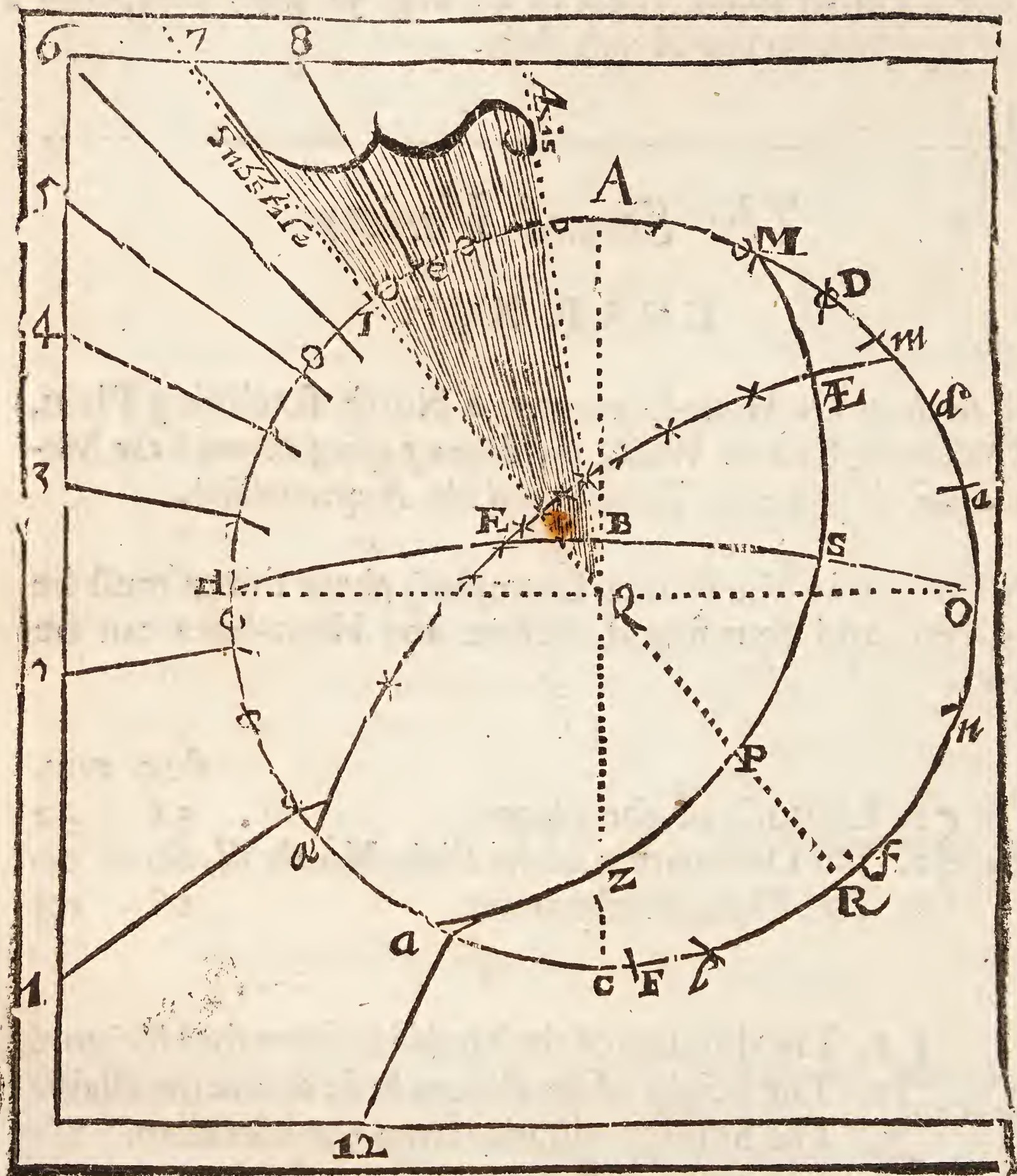
First, Describe the Circle A H C O for the plain, and cross it with the Diameters A C, and H O, for the Horizontal and Virtical lines thereof.

Secondly, (As in the last Example,) set 16 deg. the Plains Recli-

A North Dial { Declining West
Reclining

60

16



Reclination, from O to *a*, and from C to *b*, a Ruler laid from H to *a*, shall give the point B. through which, and the points H and O, the Horizontal Circle H B O is to be described. Also a Ruler laid from H to *b*, shall find the Zenith point of Z.

Thirdly,

Thirdly, Set the plains Declination 60 deg. from A to *d*, and from H to *e*: So a Ruler laid from Z to *d*, shall cut the Horizon in S the South, and laid from Z to *e*, shall cut it in E the East point thereof; and now having two points Z and S, through them you may draw the *Meridian* Circle, as hath been already taught.

Fourthly, Lay a Ruler from E to Z, it will cut the Plain in F, and 30 deg. 28 min. the Complement of the Latitude of the place, set from F to *f*, and a Ruler laid from E to *f*, will cut the *Meridian* in P the pole of the World, and 90 d. more, being set forward from *f* to *m*, and a Ruler laid from E to *m*, will cut the *Meridian* in *Æ*, the *Æquinoctial* intersection with the *Meridian*; so have you two points *Æ* and E, through which the *Æquinoctial* Circle must pass, and a right line drawn through P the pole of the World, and Q the pole of the Plain, will be the Axis of the World, and the Substilar line of the Dial.

These three Circles, *viz.* the *Horizon*, *Meridian*, and *Æquinoctial* being described, the fore-mentioned four Requisites may from thence be easily obtained. For,

1. The distance of the *Meridian* from the *Horizon*, is the Arch F H, 64 deg. 29 min.
2. The height of the Pole or Stile above the Plain P R. A Ruler laid from *e* to P, will cut the plain in *n*: So the distance R *n* measured, will be found to be 30 d. 59 min.
3. The *Substiles* distance from the *Meridian* is the Arch I M, 64 deg. 26 min.
4. The Plains difference of Longitude is the Angle *Æ P Q*, which to find, lay a Ruler from P to *Æ*; and it will cut the plain in D, the distance D I measured upon the Line of Chords, will give 76 deg. 10 min. for the Plains difference of Longitude.

To draw the Hour-lines upon the Plain.

First, Lay a Ruler upon P the Pole of the World, and \mathcal{A} , the intersection of the Meridian with the Horizon, and it will cut the plain in D, at which point begin to divide the Semicircle $\mathcal{a} I m$ into 12 equal parts, at the points $\odot \odot \odot \&c.$

Secondly, Lay a Ruler from Q to the several points $\odot \odot \odot \&c.$ and it will divide the \mathcal{A} equinoctial Circle into 12 unequal parts in the points $*** \&c.$

Thirdly, A Ruler laid from P to every of these unequal parts $*** \&c.$ will cut the plain in these marks $| | | \&c.$ dividing that into 12 other unequal parts.

Lastly, If you draw right lines from Q, through every of these marks $| | | \&c.$ they shall be the true Hour-lines belonging to your Plain.

The Stile may be either of Wire or Plate as in other Dials, and must be elevated above the Substile, to an Angle of 30 deg. 59 min. and must stand square, or at Right Angles to the plain.

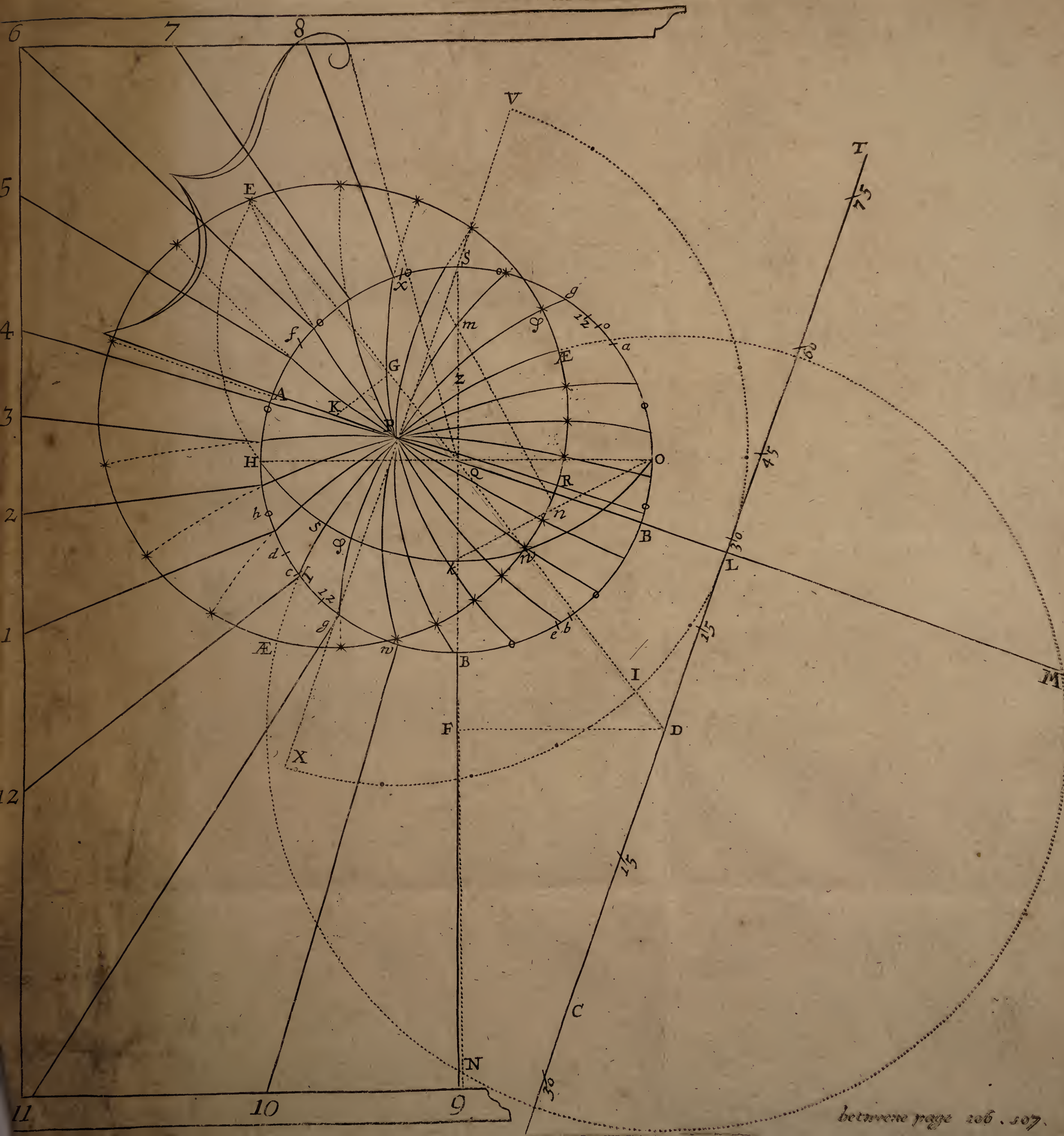
The Third Variety.

CH A P. XXV.

How to draw the Hour-lines upon a North Reclining, or Inclining Plain, Declining East or West, which intersects the Meridian between the \mathcal{A} equinoctial and the Horizon.

L Et this third and last Example of North Recliners Declining, be of a North Plain, Reclining 54 deg. and Declining Westward 60 deg. in the Latitude of London 51 deg. 32 min.

This being the third and last Variety of Declining Reclining plains, I shall be somewhat the larger in the projection thereof, than I have been in any of the foregoing; not
but



but that this Dial is to be made in all respects like (and with the same ease) as the former. But herein I shall shew at large the manner of projection, and how all the Centres are Geometrically found, and the reasons of their being in such and such lines, and at such and such distances. And also, I shall project all the Hour-lines belonging to the Plain upon the Plain it self by circular Lines, by which means the Reader may attain to a more competent knowledge in what hath been heretofore in this Treatise delivered. For from this projection following, all the aforesaid hath been deduced. And therefore I shall describe the manner of the delineating of this Dial, according to the following Proposition.

P R O P O S I T I O N.

A Circle being described, representing a Declining Reclining Dial-Plain; how thereon to place the Meridian, Horizon, Æquinoctial, Pole, Zenith, &c. with all other Requisites belonging to such a Dial. And also, to project the Meridians of the Sphere it self upon the Plain, and from thence to draw the Hour-lines upon the Dial-plain, according to their true Situation.

L Et the Circle H S O B, represent a Dial-plain in the Latitude of London 51 deg. 32 min. Declining from the North towards the West 60 deg. 00 min. and Reclining from the Zenith Northward 54 deg. 00 min.

First, Cross the Circle with the two Diameters H O, and S B, cutting each other at Right Angles in the Centre Q. And because the plain reclineth 54 deg. 30 min. take 54 deg. 30 min. out of your Line of Chords, and set that distance upon your plain, frm S to *a*, from O to *b*, and from B to *c*: Then lay a Ruler from H to *a*, and it will cut

the Line S Bin Z, so shall the point Z be the Zenith of the place.

Secondly, Lay a Ruler from H to b , it will cut the Line S Bin k , so shall k be a point in the line S B, through which the Horizon shall pass: And thus having three points H k O, you may through them describe the Horizon, whose Centre will be at m , the distance $m k$ being equal to the Secant of the Complement of the Reclination of the Plain; namely, 36 deg. — Or Geometrically thus. Draw the right line $k O$, which divide into two equal parts in n , and upon the point n , raise a perpendicular $n m$, extending it till it cut the line S Bin m , so shall m be the Centre of the Horizontal Circle H k O.

Thirdly, Lay a Ruler from H to c , it will cut the line S B (being extended) in the point N, so shall N be the Nadir point.

Fourthly, Because the Plain declines 60 deg. from the North Westward; set 60 deg. from B to d , and laying a Ruler to Z the Zenith, (which is also the Pole of the Horizon) to d , it will cut the Horizon in S, through which point the *Meridian* must pass.

Fifthly, Take (always) 90 deg. of your Chord, and set that distance from d to e , and laying a Ruler from Z to e , it will cut the Horizon in W the West point thereof, and a line drawn from W, through Q the Centre of your plain, will cut the Horizon (if you extend it as here is done) in E, the East point thereof, and in some part of this line (extended if need require) will the Centre of the Meridian be; and where that point will fall may be thus found,

Sixthly, Divide the line Z N into two equal parts in F, and upon F erect the perpendicular F D, cutting the Line Q W (extended) in D, so shall D be the Centre of the Meridian of the place.

Seventhly, If with your Compasses you take the distance D P, and with that extent upon D, as a Centre, describe a Circle, you shall find that Circle exactly to pass through the respective points Z and N, if there be no former error committed in your work.

Eighthly,

Eighthly, Because the height of the Pole above the Horizon, is equal to the Latitude of the place, viz. at London 51 deg. 32 min. set off 51 deg. 32 min. upon the *Meridian* from S to P, in this manner.

Ninthly, Lay a Ruler from W, the West point of the Horizon, (which is also the Pole of the *Meridian*) to S and it will cut the Plain in *h*, then set 51 deg 32 min. from *h* to *f*. A Ruler laid from W to *f*, it will cut the *Meridian* in P, so is P the Pole of the World, distant from Z the Zenith, 38 deg. 28 min. and a Line drawn through P the Pole of the World, and Q the Centre of the Plain, will be the Axis of the World, and (extended) will cut the *Meridian* in M the South Pole.

Tenthly, The *Meridian* and *Horizon* being thus drawn, it is easie to describe the *Æquinoctial*, for if you consider the position of that Circle in the Sphere it self, you know that it always passes through the East and West points of the *Horizon*, and cutteth the *Meridian* at right angles, it being in all places 90 deg. distant from either of the Poles. Wherefore, if upon W, (the Pole of the *Meridian*) you lay a Ruler to P, the Pole of the World, it will cut the Plain in *f*, and if you set 90 deg from *f* to *g*, and lay a Ruler from W to *g*, it will cut the *Meridian* in *Æ*, so have you three points, through which the *Æquinoctial* must pass, namely E *Æ* and W, and the Centre of the *Æquinoctial* will always be in the Axis of the World, extended if need require. To find which, you must,

Eleventhly, Divide the Line W E into two equal parts in G, and from the point G, upon the line E W, erect the perpendicular G K, cutting the Axis of the World in K, so shall K be the Centre of the *Æquinoctial*, wherefore, if upon K as a Centre, with the distance K W, you describe a Circle, that shall be the *Æquinoctial*, and (if your work be true) shall pass through the points E *Æ* and W: Then for the dividing of the *Æquinoctial*,

Twelfthly,

Twelfthly, Lay a Ruler to P the pole of the World, (which is also the pole of the *Æquinoctial*) to \mathcal{A} , the intersection of the Meridian and *Æquinoctial*, and it will cut the plain in the point 12 at which point you must begin to divide the Circle representing your Reclining Declining plain into 24 equal parts at the points $\odot \odot \odot \&c.$ This done, lay the Ruler to the point P , and every of the 24 equal parts $\odot \odot \odot$, and you shall find it to cut the *Æquinoctial* Circle in the points $* * * *$ $\&c.$ dividing that Circle into 24 unequal parts, through which unequal parts, and the two poles of the World P and M , must all the Hour-Circles pass. For the describing whereof you must,

Thirteenthly, Divide the line $P M$ into two equal parts in the point L , [or, from the point D , the Centre of the Meridian, let fall a perpendicular upon the Axis of the World, which will fall in the same point L ,] and through the point L , draw an infinite right line at right angles to $P M$, namely, the Line $C T$, for in that line will the Centres of all the Hour-circles be found, and the manner how to find them, is thus (one way) to be effected.

Fourteenthly, Upon the point P as a Centre, at the distance $P L$, [or to any other Radius of a Line of Chords] describe the Semicircle $X L V$, and divide it into 12 equal parts at the points $\dots \&c.$ beginning your division at the point J , which is, where the Ruler being laid from P to D (the Centre of the Meridian) cuts this last drawn Circle. Then laying a Ruler from P , upon each of these divisions, you shall find it to cut the line $C T$ in the points $15, 30, 45, 60, \&c.$ on either side of the point D . And here note, that 15 is the Centre of the first hours distance from the *Meridian* on either side thereof, 30 the Centre of the second, and 45 of the third hours distance from the *Meridian*, $\&c.$

Fifteenthly, If you place one foot of your Compasses upon 15 , and extend the other to P the Pole of the World, and with that distance describe a Circle, that Circle shall be the

the first hour from the *Meridian*, and (if your work be true) shall pass through M the South Pole, and also through $\phi \phi$, the two first unequal divisions of the *Æquinoctial Circle*, and so all the rest.

Lastly, If from Q the Centre of your Plain, and the respective points where the Hour-circles cut the Plain, you draw strait lines, those shall be the true Hour-lines proper for such a Declination and Reclination, as you formed your projection for.

Now the Requisites belonging to this, and the like Declining Reclining Plains, are,

		deg.	min.
1. The height of the Pole above the Plain.	repre- sented by	P A	54 43
2. The distance of the Meridian and Horizon.		H Γ	53 31
3. The distance of the Substile from the Meridian.		Γ A	56 41
4. The Angle between the two Meridians.		Æ P R	61 47

All which may be measured upon the projection, and so their quantities found. As,

1. To find P A, Lay a Ruler from P to w , where the *Æquinoctial* and the plain do intersect, and the Ruler will cut the plain on the other side at x , so A x measured upon the Line of Chords, will be 54 d. 43 m. the height of the pole above the Plain, [or P Q measured upon a line of half Tangents, will contain 35 d. 17 min.] the Complement thereof.
2. To find H Γ, the arch H Γ measured upon the Line of Chords, will give 53 deg. 31 min. the distance of the Meridian from the Horizon.
3. To find Γ A, the Arch Γ A measured upon the Line of Chords,

Chords, will give 56 deg. 41 min. the distance of the Substile from the Meridian

4. To find Æ P Q , Lay a Ruler to P the Pole of the World, and Æ the intersection of the Meridian and the Æ quinoctial, and it will cut the plain in θ , the arch θB , measured upon the Line of Chords, will be found to contain 61 deg. 47 min. which is the Angle between the two Meridians.

Thus have you in this Scheme delivered the true and genuine way of delineating of Sun Dials deduced from the Sphere it self, by which the reason of all that hath been before delivered, is rendred obvious, and sufficiently demonstrative for this place. But here you see that the Centres of the Meridians or Hour-circles fall out to be very remote, and that there will be required a large Tangent line for their description, which will (for the most part) run out very far, and sometimes, almost to an infinite excursion. I therefore chose rather to shew how the Hour-lines might be drawn without having any regard to this Tangent line, or without projecting of the Hour-lines upon the Circular-plain, and therefore the ways before delivered are far more apt for practice than this, though this be more satisfactory to the inquisitive Reader, who will not be satisfied only with the doing, but of the understanding as well of what he does, and it is for the satisfaction of such, that I have here added this Proposition.

CHAP. XXVII.

Concerning Inclining Plains, both Direct and Declining.

OF Reclining Plains there are but two sorts, as hath been before instanced, and those are either *Direct* or *Declining*. The *Direct* are those Reclining Plains which do directly behold the *East, West, North, or South* points of the *Horizon*.

Horizon. And the *Decliners* are those which (besides their Reclination from the Zenith) do respect two of the fore-mentioned Cardinal points, as,

- (1.) The *South* and the *West*.
- (2.) The *North* and the *West*.
- (3.) The *South* and the *East*.
- Or, (4.) The *North* and the *East*.

The { First }
 { Second } fort are { South }
 { Third } called { North } declining West } Reclining
 { Fourth } { South }
 { North } declining East }

I also before intimated, and gave Examples, that of direct Recliners, there were three sorts, *viz.*

1. Such as Reclining from the Zenith, do behold either the due *East*, or due *West* points of the Horizon; and of this sort there is only one kind, and no Variety in any case.----

2. *South Recliners*, of which there are three Varieties.----

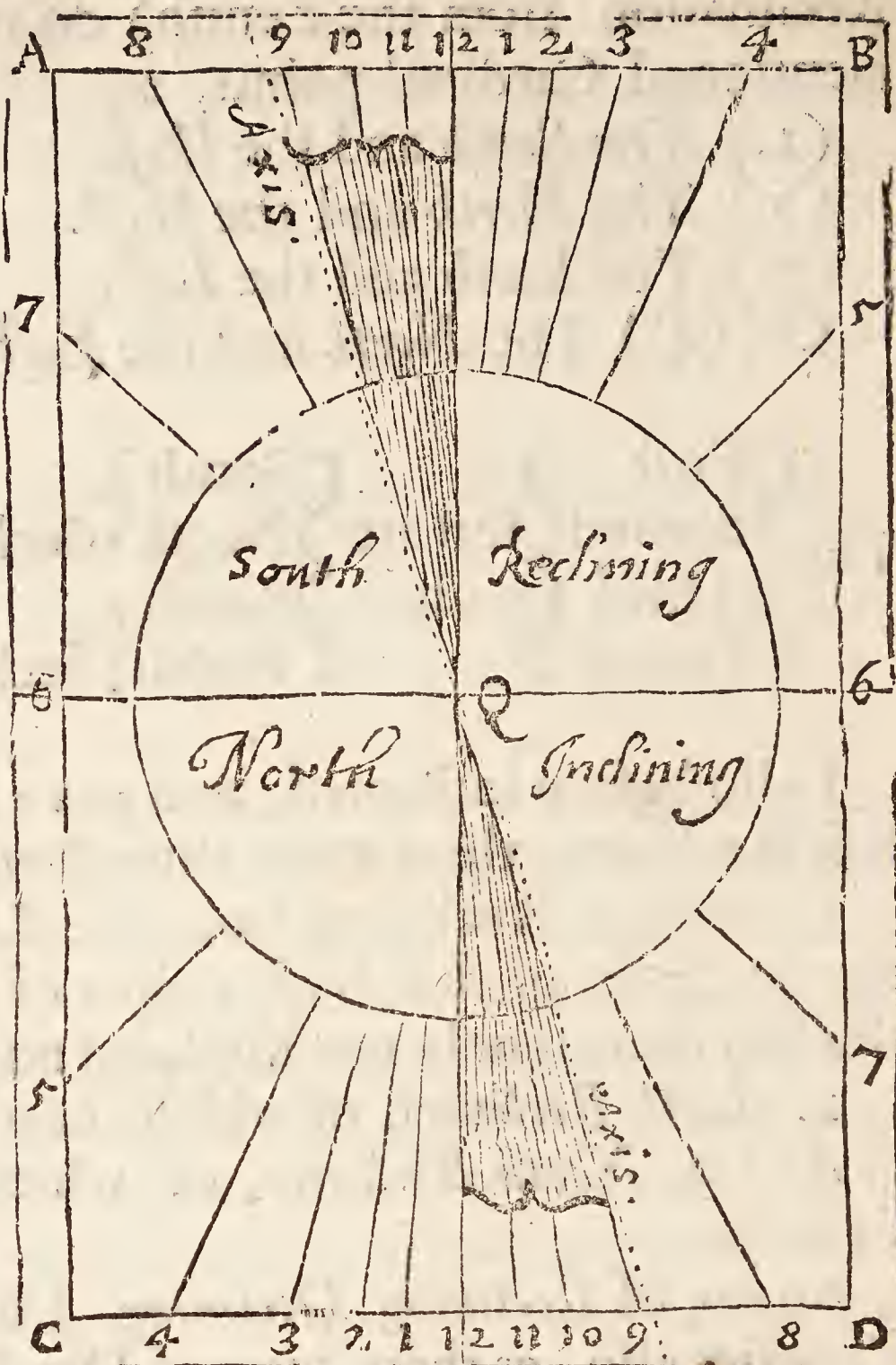
And 3. *North Recliners*, of which also there are three Varieties.

Again, of *Reclining Declining*, I told you there were six Varieties also, as there were of Direct Recliners, *viz.* Three of South Declining Plains Reclining, and as many of North Reclining Declining Plains; of all which I have given Examples, and it may be now expected that I should do the like for the Inclining Plains opposite to them, of which there are also as many Varieties, but seeing that the making of the Reclining Dial, whether Direct or Declining doth also make the Inclining Dial, whether Direct or Declining opposite thereunto, I shall save the labour, and commend to the ingenious Reader some few Rules by which he shall easily frame the Inclining Dial out of the Recliner. And,

I. Of North and South Incliners.

I will take for Example a South Plain Reclining 55 deg. which is the Third Variety of South Recliners, and I would from that deduce the Hour-lines proper for a North plain Inclining as much, viz. 55 deg. And it is easily effected. For,

If you draw the Hour-lines of the South Recliner 6 A B 6, and the Stile thereof also, quite through the Centre Q, to the opposite part of the Plain, 6 C D 6, and set the same



numbers to the hours on the right hand in the Recliner, and the contrary, as the Figure clearly demonstrates: And let the Axis in the North Incliner point downwards to the South Pole, as the Axis in the South Recliner doth upwards to the North Pole, and your Dial is finished. Or you may effect this work by pricking off the Hour-lines through the Paper, and turning it upside down, and that will effect the same thing, only changing of the names of the hours. Or again, if you turn the South Reclining Plain, 6 A B 6 about, upon the Centre Q, till the Line A B come to be in the place of C D, then will the Hours, Stile and all, be truly named and posited; and the very South Recliner will now become the North Incliner without any Alteration.

II. *Of East and West Incliners.*

There is little difference in drawing of the East or West Inclining Dials from the Reclining Dials opposite to them, than there was of drawing of the North Incliner before, from the South Recliner: For,

In the Example of the East and West Reclining and Inclining Dial, before going Chapter 10. The Dial as it there stands, represents an East or West Reclining Plain. But if you turn the Dial about upon the Centre Q, till the letter N come to be in the place of the letter S, in that Figure, then will the same Dial represent both an East and West Dial Inclining 35 deg. as now it doth an East or West Reclining as much. The Substile, Stile, Meridian, and the rest of the Hour-lines retaining the same names or denominations, as now they do.

III. *Of North or South Declining Inclining Plains.*

Of North and South Reclining Declining Plains, there were Six Varieties, Examples of each have been largely given. There are as many of North and South Incliners, but seeing they may be so easily deduced out of their opposite Recliners, I shall forbear giving examples, and the way is not much differing from the Rules before given for Direct Reclining and Inclining Plains. For seeing the Reclination is alike proper to each, and the Deflexion of the Substile from the Meridian in the Declinations do so directly agree, they may both be reduced to one and the same Dial as the other were.

Thus, If any Reclining Dial be so inverted, that the upper part thereof, become the nether, and after this inversion the right side of the Recliner, become the left side of the Incliner, and the contrary, the Inclining Dial having the same declination, shall be framed out of the Recliner, and the contrary. Only the denominations of the Hours must be changed. For the Forenoon hours in the Recliner, will be the Afternoon hours in the Incliner, and the Afternoon hours of the upper Dial, the Forenoon hours of the nether.

CHAP. XXVIII.

A General Rule to know which Pole, whether the North or the South is to be elevated over any Plain.

THe Stile of every Dial respecteth (or rather lieth parallel with) the Axis of the World, and always pointeth upwards or downwards, to one of the Poles. Now when you have drawn your Dial (though truly) you may be to seek, whether it be the North or the South Pole that must be elevated; wherefore to avoid any mistake, and to inform you which Pole is to be elevated. Observe this General Rule.

Upon all Upright Plains, { South }
whether direct or de- { North } side the { South } Pole.
clining, upon the { North }

Upon all East { Recliners } the { North } Pole.
and West { Incliners } { South }

Upon all { North Recliners } whether { North } Pole..
{ South Incliners } Direct or Declining { South }

Up- { South Re- } whe- { If the } Zenith { and } South
on { cliners } ther { Plain } Nadir { the } North Pole.
all { North In- } or de- { pas between } Horizon { Pole, } South
{ cliners } clin- ing { the }

This Rule being duly observed, there will be no difficulty to find which Pole is elevated.

A Second

A

Second Way OF DIALLING,

GEOMETRICALLY Performed.

PART II.

IN the foregoing First Part, you have a most absolute and perfect way of delineating of *Sun-Dials* upon all sorts of *Plain Superficies* in what position soever situate, and in any Latitude, whether the Plains be *Direct*, or do *Decline*, or whether they both *Decline* or *Recline*: And also you may there find, not only the manner how to make *Dials*, but to know the *Grounds* and *Reason* of *Dials*, deduced from the *Sphere* or *Globe* projected *in plano*, upon the *Dial-Plains Superficies*.

But notwithstanding the Exactness and Rationality of delineating of Hour-lines upon all *Plains*, and in all Places, as is before taught; yet the ways there delivered, may (in some cases, at some times) be found inconvenient to put in practice: As (1) When the *Centres* of some of the *Circles* fall out to be very remote. (2) When

(2) When the unequal Divisions of the *Æquinoctial* Circle come very near or close together, which they will always do, when the Pole hath but small Elevation above the Plain, and such like. For the removal of which Inconveniencies, I shall in this *Second Part* add another *Geometrical Way of Dialling*, which shall be both Plain, Easie, Exact, and of Quick dispatch; and all of it performed by strait Lines, and not by Circular Lines, as the former way requires. And moreover, this *Second Way* hath a Convenience, which most other *Geometrical* ways of *Dialling* are culpable of, namely, to out-run the Limits of the Plain, by almost infinite Excursions: For in this way, having first made a *Preparative Scheme* upon Paper (or Pastboard rather) you shall have very few Lines to draw upon the Dial-plain but the Hour-lines themselves.

In this *Second Way*, I shall be brief, beginning first to shew how to describe the Hour-lines upon *Upright Declining Plains*; referring the delineation of Hours upon the *Horizontal full North, South, East and West Plains* (whether Upright or Reclining) till afterwards: And the Reason for my so doing, will of it self appear, when I shall come to treat of them. Wherefore to proceed,

Section I.

How to draw Hour-lines upon an Upright South Plain Declining from the South towards the West 20 deg. in the Latitude of London 51 deg. 32 min.

HAVING the *Latitude of the Place*, and the *Declination of your Plain* given, before you come to draw the Hour-lines upon the Plain, you must first draw your *Preparative Scheme*, as followeth.

I. *How to draw a Preparative Scheme suitable to any Declination in any Latitude.*

First, With 60 deg. or the Radius of your Scale of Chords, describe the Quadrant of a Circle A B D, extending the side B A to C, so that A C be equal to A B: And then draw the right line D C.

Secondly, On the point B, erect the perpendicular B m.

Thirdly, Take 51 deg. 30 min. (the Latitude) out of your Scale of Chords, and set them from B to F, and from D to G, and laying a Ruler from A, to F and G, draw the two Lines F K, and G I.

Fourthly, From the point G, draw the Line G H, parallel to D A, or perpendicular to B A.

Fifthly, Take 20 deg. (the Plains Declination) out of your Scale of Chords, and set them from D to E, and through the point E, draw the Line E L, parallel to D A.

Sixthly, With 60 deg. (or the Radius of your Scale of Chords) taken in your Compasses, set one foot in the point D, and with the other describe the Arch A O, which divide into three equal parts, in the points P and Q, for the whole hours, each of which three Hour-spaces A P, P Q, and Q O, divide into four equal parts at * * *, * * *, * * *, for halves and quarters of hours. Which done, if you lay a Ruler to the point D, and the points P and Q, the Ruler will cut the Line A C in the points 2 10, and 1 11, and by these points the Line A C is divided into four unequal parts in the points 39, 2 10, 1 11 and 12, representing three hours. And if from D, you lay a Ruler over the several points * * * &c. they shall divide the several spaces in the Hour-line A C into four unequal parts for halves and Quarters of Hours. And thus is your *Preparative Scheme* so far finished. Wherefore now let us proceed,

II. To draw the Meridian, Stile, Substile, and Hour-lines upon the Plain it self.

First, Upon your Dial-plain, draw a Right Line as S T, for the *Meridian*, and Hour-line of 12. Upon which, assign any convenient point, as R, for the Centre of your Dial; through which point R, draw the Line R W, perpendicular to S T.

Secondly, Out of your *Preparative Scheme* take the Line B K, and set it upon your Dial-plain, from R to T; also, from the *Preparative Scheme*, take B I, and set it on your Dial-plain from R to W, on the right hand, because the Plain declineth West, and from T to V, make the Rect-angled Parallelogram R W T V on the East side.

Thirdly, Out of the *Preparative Scheme*, take the Line L A, and set it upon the Dial-plain from T to X, and from W to \odot , and draw the Lines R X for the Substilar Line, and R \odot for the Hour-line of Six, which draw quite through the Centre R.

Fourthly, Out of your *Preparative Scheme*, take the Line E L, and set it upon your Dial-plain from R to 12, and from X to Y, perpendicular to R X, and draw the Line R Y for the Axis (or Stile of your Dial.)

Fifthly, Out of your *Preparative Scheme*, take the line G H, and set it on your Dial-plain from R to Z, and draw the line Z 6, parallel to W Y, till it cut the Hour-line of Six in 6.

Sixthly, Make R 6 above the Centre, equal to R 6 below the Centre, and draw the two Lines 12 6, and 12 6.

Seventhly, Out of your *Dial-plain*, take the length of the Lines 12 6, and 12 6, and set them upon the *Preparative Scheme* from B to *b*, and from B to *a*. And laying a Ruler from C to *a*, draw the Lines M C, and N C.

Lastly, From the point A or 3, 9, take the nearest distance to the Line N C, and set that distance upon your *Dial-plain* from

from 12 to 9, or from 6 to 9, for it will (if you work truly) divide the Line 6, 12 into two equal parts in 9. Also set one foot of the Compasses in the point 2, 10 in the Line A C of the *Preparative Scheme*, with the other take the nearest distance to the Line N C, and set that distance upon your *Dial-plain*, from 12 to 8, and from 6 to 10. ----- Again, setting one foot of the Compasses in the point 1, 11, in the Line A C of the *Preparative Scheme*, with the other, take the nearest distance to the Line N C, and set that distance from 12 to 11, and from 6 to 7. So is the longer Line 6, 12 on your *Dial-plain*, divided into Six unequal parts in the points 7, 8, 9, 10 and 11; through which points, Lines drawn from the Centre R, shall be the true *Fore-noon Hours*.

For the Afternoon hours, the shorter Line 12, 6. on your *Dial-plain*, must be divided from the Line A C in the *Preparative Scheme*, as the longer Line 12, 6 was before divided; by taking the least distance from A or 9, 3 to the line M C, and setting it from 12 to 3, or from 6 to 3. — Also the least distance from 2, 10, to M C, in the *Preparative Scheme*, will reach from 12 to 2, and from 6 to 4. ---- Likewise the least distance taken from 1, 11, to the Line M C, in the *Preparative Scheme*, will reach from 12 to 1, and from 6 to 5. So is the shorter Line 12 6, on the *Dial-Plain*, divided into six unequal parts in the Points 1, 2, 3, 4, 5. Through which points, and the Centre R, right Lines being drawn, they shall be the true Afternoon Hour-lines upon the Plain. And so is your Dial finished.

If you would insert the Halfs and the Quarters of Hours into your Plain. you may easily do it, if from the *Preparative Scheme* you take the nearest distance from the Half and Quarter points in the Line A C, and transfer them to the Lines 12, 6, and 12, 6, in the *Dial-Plain*.

Section. I I.

How to describe Hour-lines upon the Horizontal Full South, North, East and West Erect or Reclining Plains.

IN these kind of Plains, which directly behold the Four Cardinal North, South, East and West points, the Latitude of the place, and Reclination of the Plain being known, there is nothing required, but to know the *Elevation, or height of the Pole above the Plain*, which, how to find, is sufficiently taught in the *Fourth and Fifth Sections* of the *Fourth Part* of this Book: And therefore I shall not here repeat the same again, but refer you to those fore-mentioned Fourth and Fifth Sections of the *Fourth Part* hereof. Wherefore, to draw Hours upon any of these *Erect, Direct, or Direct Reclining Plains*, when the height of the Pole or Stile above the Plain is found, you have no more to do; but,

First, Draw a right line A B for the Hour-line of Six, and another at right Angles thereto, for the Hour-line of 12, as the Line \odot X.

Secondly, With the Radius of your Line of Chords 60 d. upon \odot as a Centre, describe the Semicircle A X B. And the height of the Pole above the Plain being known, (as for an *Horizontal Dial* for London, where the Pole is elevated 51 deg. 30 min.) Take 51 deg. 30 min. from your Chord, and set them upon the Semicircle from X to F, and from X to I, and through the points F and I, draw the Lines 6 F and 6 I, parallel to \odot X, and draw the Lines X 6 and X 6 on either side of the Meridian.

Thirdly, (Having recourse to your former *Preparative Scheme*) take in your Compasses the length of the Line X 6, and set it upon the *Preparative Scheme* from B to c, and laying a Ruler from A to c, draw the pricked Line C Δ .

Fourthly,

Fourthly, In the *Preparative Scheme* from the point A or 9, 3, take the nearest distance to the pricked Line ΔC , and set it upon the Lines X 6, and X 6, from X to 3, and from X to 9. Also from the point 2, 10, in the Line A C of the *Preparative Scheme*, take the nearest distance to the pricked Line ΔD , and that distance set upon the Lines X 6, and X 6, from X to 10 and 2, and from 6 to 8, and from 6 to 4. — Likewise, take the nearest distance from the point 1, 11, in the Line A C of the *Preparative Scheme*, to the pricked line ΔC , which distance will reach from X to 11, and from X to 1, and also from 6 to 5, and from 6 to 7. So are the two Lines X 6 and X 6 divided each of them into six unequal parts, the one in the points 1, 2, 3, 4, and 5, and the other in the points 11, 10, 9, 8 and 7. Through which points, right Lines drawn from the Centre \odot , they shall be the true Hour-lines proper for an *Horizontal Dial*, for the Latitude of *London* 51 deg. 32 min.

For the *Stile* of this Dial, a Line drawn from the Centre \odot , through either of the points F and I, shall represent the *Axis of the World*, or *Stile of the Dial*.

For a Vertical or Erect South Dial for the same Latitude 51 deg. 32 min.

The height of the Pole above a *South Plain* in the Latitude of 51 deg. 32 min. is 38 deg. 28 min. the Complement of the Latitude. Wherefore,

First, Take 38 deg. 28 min. from your Scale of Chords, and set them from X to G, and from X to H, and draw the Lines X M and X D, parallel to $\odot X$.

Secondly, Take the length of the Line X M and X D, and apply it to your *Preparative Scheme*, setting it from B to d, and laying a Ruler from C to d, draw another pricked Line C \mathcal{A} .

Thirdly, The nearest distances taken from the points A, 2, 10, and 1, 11, in the Line A C of the *Preparative Scheme*, will

will (being transferred from thence to the *Dial-plain*) divide the Lines X M and X D, each of them into six unequal parts, through which divisions, and the Centre \odot , Lines being drawn, they shall be the true Hour-lines of an *Erect South Dial* in the Latitude of *London*.

A Line drawn from \odot (the Centre of the Dial) through the points H or G, shall represent the *Axis of the World*, and be the *Stile* of this *Dial*.

For a Direct North Reclining Plain.

Let our Example be of a *Direct North Plain Reclining* from the *Zenith* 25 deg. and such a *Dial* is described in the 17th. Chapter of the *First Part*, and the height of the *Pole* or *Stile* above the *Plain*, was there found to be 63 d. 28 min. And so it will be found to be by the Rule delivered in the *Fifth Section* of the *Fourth Part* of this Book.

First, The height of the *Stile* being found to be 63 d. 28 min. take 63 deg. 28 min. from the Scale of Chords, and set them from X to E, and from X to K, and draw the Lines E C, and R D, parallel to the Meridian \odot X. Also, draw the Lines X C and X D.

Secondly, Take the length of the Line X C or X D, and set it upon the *Preparative Scheme* from B to e, and draw a third pricked Line as e C.

Thirdly, The nearest distances taken from the points A, 2, 10, and 1, 11, in the Line A C, shall (being set upon the Lines X C and X D) divide them each into Six unequal parts; through which, and the Centre \odot , right lines being drawn, they shall be the true Hour-lines of a *North Direct Plain Reclining* 25 deg. the Latitude of *London*.

The *Stile* must be drawn from the Centre \odot , through the point E or K.

For Direct East or West Plains, whether Erect or Reclining.

For *Erect Direct Plains*, where the Hour-lines are parallel one to another, the Stile or Pole having no Elevation, the best way to make them, is, as is directed in the *Sixth Chapter* of the *First Part*. And therefore in this place, nothing more need be said concerning them. But,

For East and West Recliners.

The best way to deal with these kind of Plains, is to refer them to a *new Latitude*, and to a *new Declination* in that *new Latitude*, both which are easily attained by this following *GENERAL RULE*.

1. *The New Latitude, is always the Complement of the Old Latitude.*
2. *The New Declination in that New Latitude is the Complement of the Reclination.*

So that if a *Direct East Plain*, in the Latitude of *London* 51 deg. 32 min. should Recline 40 deg. and you would find the *New Latitude* and *New Declination*;

First, The Complement of the *Old Latitude* 51 deg. 32 min. is 38 deg. 28 min. And that must be the *New Latitude*.

Secondly, The Reclination being 40 deg. The Complement thereof is 50 deg. And that is the *New Declination*.

So that if (by the directions of the *First Section* hereof) you make an *Erect Dial* to decline 50 deg. in the Latitude of 38 deg. 28 min. that *Dial* shall serve for an *East or West Dial*, Reclining 40 d. in the Latitude of 51 d. 32 m.

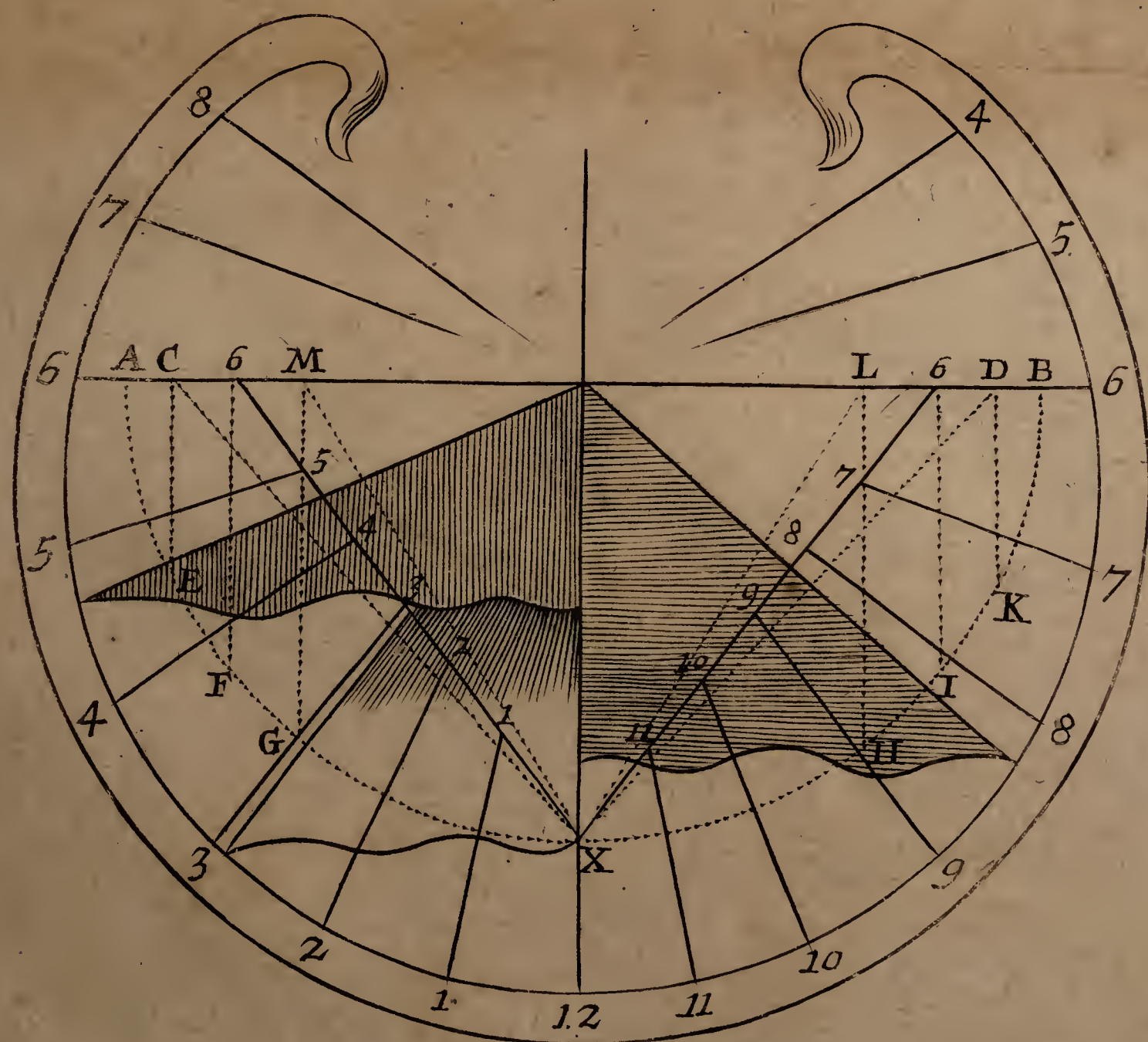
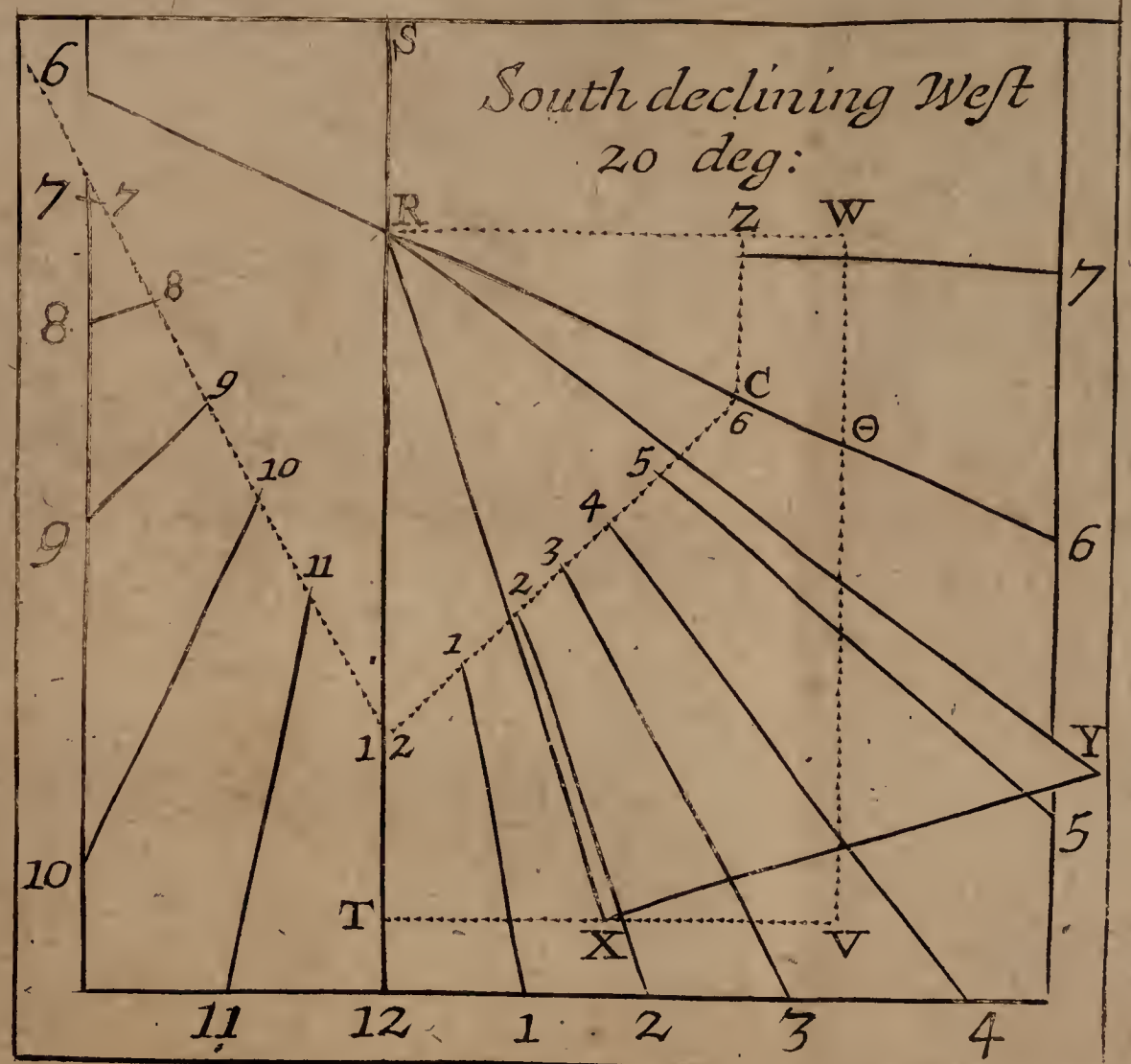
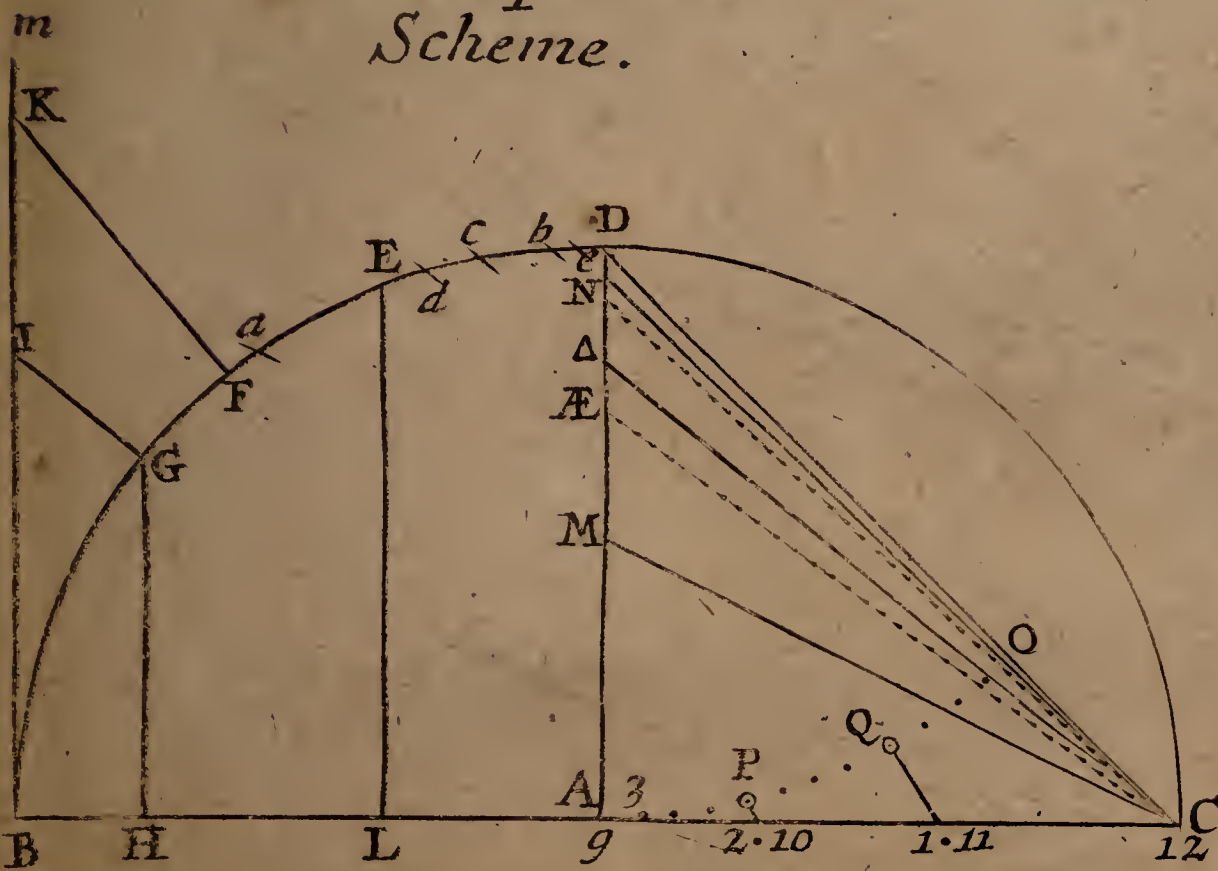
Thirdly, Although this *Declining Plain* be truly made,
yet

yet the placing of it upon the *Dial-Plain*, differeth from *Erect Plains* : For, in all *Erect Declining Plains*, the Hour-line of 12 is always perpendicular to the *Horizontal Line of the Plain*. So in all *East and West Reclining Plains*, the Hour-line of 12 must lie parallel to the *Horizontal Line of the Plain*. As you may see in the *Figure Chap. 10, of Part the First*.

It may here be expected, that I should say something concerning *Declining Reclining Plains*, which this *Geometrical* way will very well perform, by referring them to a *New Latitude*, and a *New Declination*, where they will become *Erect Declining Plains*; but for that the performance thereof, this way, would require many Schemes, and that there are *Three* ways in this Book, already taught, how to effect the same by other means, I thought good to omit them in this place; and to give Examples in *Erect Direct*, in *Direct Reclining*, and in *Erect Declining Plains*, (as being of all others the most useful.) And so I shall conclude this *Second Geometrical Way of Dialling*.

The

The Preparative Scheme.



The *ART* of
DIALLING,
INSTRUMENTALLY

PERFORMED:

By a Plain, Cheap, and Portable Instrument, accommodated with Lines necessary for that purpose.

PART. III.

CHAP. I.

A Description of the Instrument.

THE Instrument may most conveniently be made upon a thin Plate of Brass (the thinner the better.) Let it be made in the form of a Right-angled Triangle, one of the sides containing the right Angle being in the Figure marked with A B, let it be divided as a Line of Natural Sines, and the other side noted with A C, let be divided as a line of Natural Tangents, of such a length that it may contain 75 degrees at the least of the same Radius with the Line of Sines. Let both the Sines and Tangents be numbered from A, by 10, 20, 30, &c. according to the usual manner, the Sines to 90 deg. and the Tangents to 75 or upwards — The divisions of both these lines must be graduated

graduated close to the outer edges of the Brass as Protractors are usually divided, and the Metal not exceeding that thickness. — On the third edge B C, is graduated a line of double Tangents of any Radius, such as the line is capable to receive 45 deg. on either side from the middle thereof, from D to E 45 deg. and from D to F as many; which Tangents are to be numbred not into degrees of a Circle, but into degrees of Time, allowing 15 deg. to 1 hour, 30 for 2 hours, and 45 for 3 hours, and the other intermediate parts for Halfs and Quarters, and in larger Instruments into smaller parts — This I call the Scale of hours, and must be numbred as in the Figure XII, standing at one end, and VI at the other end thereof, IX and III in the middle, and the rest in order, as in the Figure — And it were not amiss, if the Tangent line A C were marked at the degrees of Time, as well as into degrees of the Circle, which will be useful in the description of East, West, and Æquinoctial Dials both direct and declining.

In some convenient place of the Plate you may have one, two or three Lines of Chords to several Radius's, which will perform the work of the First Part of this Book, and will also be serviceable in this.

Also it would be necessary that the other side of the Plate were graduated for the Lines of Sines and Tangents, in all respects, as the fore-side: But for the line of hours it were not amiss to have two or three of them of several lengths, as in practice you may find occasion for, though one will do all. And this may easily and commodiously be done if the middle of the Plate be cut out, and then on all the inner edges of the Plate, you may have several Lines of hours, and between them Chords also. A Quadrant also may be projected upon this Instrument, and then it will be serviceable to take a declination of a Plain; for by it you may find the Azimuth. The Instrument thus fitted will be very portable, and very exact and easie in practice. For these last mentioned parts, I leave them to the discretion of the Artificer, or
the

the will of the Owner, the first three lines being sufficient to perform all the following works. This Instrument thus made, I call (in respect of the Figure of it) an *Horological Trigon*. The uses whereof are exhibited in the following Chapters.

CHAP. II.

How to draw the Hour-lines upon all sorts of Direct Plains, by help of the Horological Trigon.

Dials may be delineated upon all sorts of Plain Superficies, by help of this *TRIGONAL INSTRUMENT*. And that I may retain herein the like Method as I have observed in the Three foregoing *Treatises*, I shall begin with the *Direct Plains* first, and from them proceed to the *Oblique*. And in my prosecution hereof, I shall more lightly pass over such things as I have in the first Part more particularly handled, so by this means the subsequent *Treatise* will be the more brief, and the less cumbred with Precepts: And I shall begin with such Plains as are *Direct*, whether *Erect* or *Reclining*.

Section I.

How to draw the Hour-lines upon a Vertical or Horizontal Plain, as also upon any direct North or South Plain in any Latitude, whether Erect or Reclining.

THere is no difference in the construction of these several sorts of Dials, the height of the Pole or Stile above the Plain being first attained, which how to effect, is at large taught Geometrically in the First and Second

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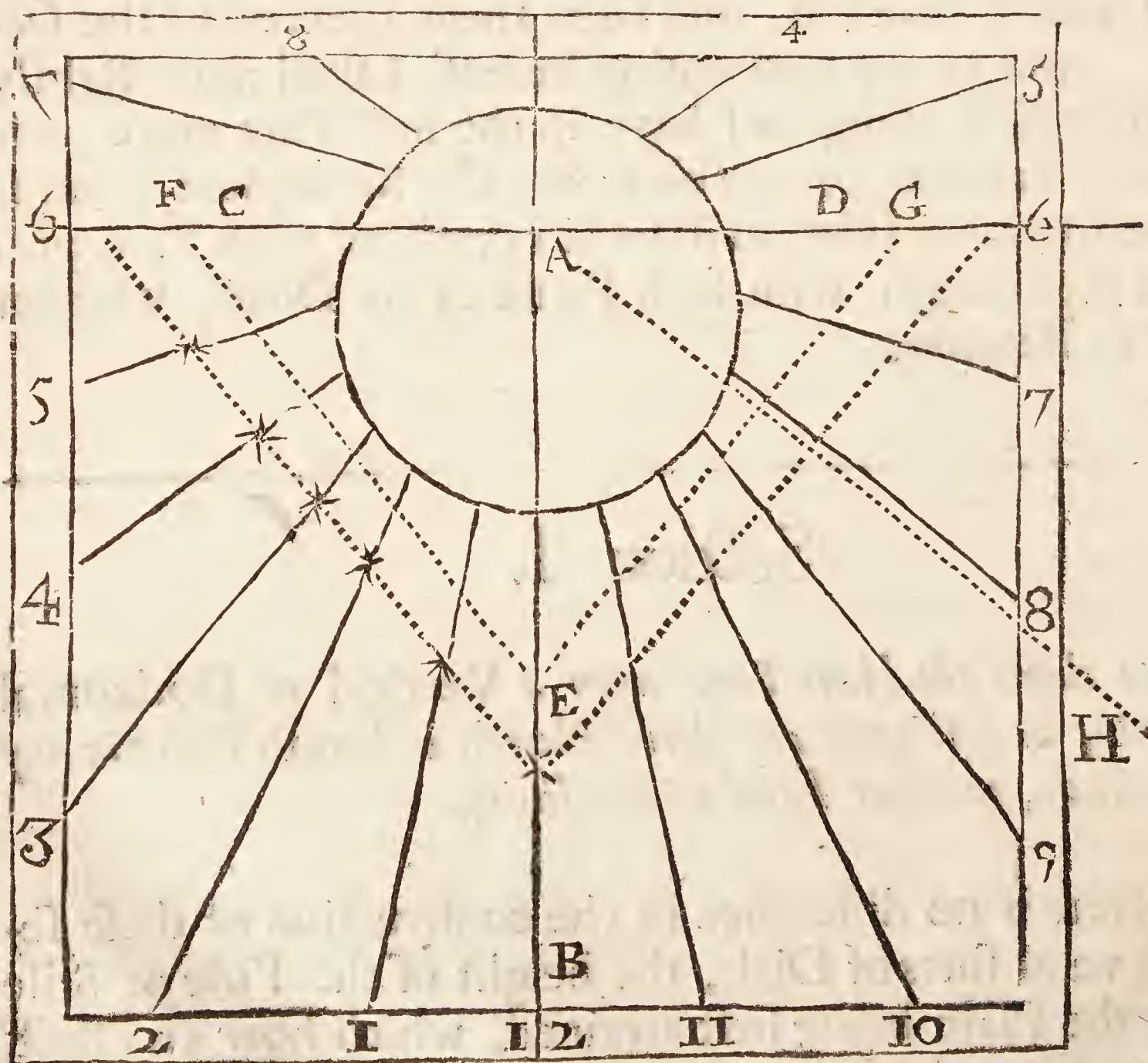
Part,

Part, Chap. 3. and in the Fourth Part, Sect. 1. and therefore in this place will be needless to recite. Wherefore let us take one Example for all, *viz.*

To draw the Hour-lines on a Vertical or Horizontal Plain, in the Latitude 51 deg. 32 min.

First, Upon your Plain (or upon a Sheet of Paper) draw a right line A B for the Meridian (or hour-line of 12,) and assigning any point therein (as A) for the Centre of your Dial, through it draw the line C A D at right Angles for the Hour-line of 6.

Secondly, Lay the Centre of your Trigon, to the Centre of your Dial, so that the Tangent-line thereof may lie upon the Line of 12, and the Line of Sines upon the Line of Six.



Thirdly, With a Needle (or protracting Pin) make a Mark

Mark upon the Meridian Line, against (the Radius or) 45 deg. as the point E. And upon the line of 6 make another mark, against the Sine of your Stiles height (in this Example against 51 deg. 32 min.) as at F, and draw the line E F. Do the like on the other side of the Meridian line, by making A G equal to A F, and draw the Line E G.

Fourthly, Divide the lines E F and E G (each of them) into two equal parts, in the points 9 and 3, and from the Centre of your Dial through these points 9 and 3, draw two right lines, which shall be the Hour-lines of 9 and 3 of the Clock.

Fifthly, For the drawing of the rest of the hours, lay the Line of Hours upon your Trigon to your Plain, in such manner, that the point or end thereof noted with 6, and the other end or point thereof noted with 12, may justly touch the Hour-lines of 12 and 6 upon your Dial-plain, and move the Line of hours between the two Hour-lines of 12 and 6 backwards or forwards (as occasion shall require) till the middle of the Line of Hours, noted with the hours 9 and 3, rest just upon the Hour-line of 9 or 3 upon your Plain ---- Your Line of Hours lying in this position with your protracting Pin (or Needle) make marks upon your Plain, against every Hour, half and Quarter, as the points *** &c. ----- And from the Centre of your Dial, (through these respective points) draw right Lines and they shall be the true Hour-lines proper to your Plain.

Do the like on the other side of the Meridian for the Afternoon hours, and your Hour-lines are all drawn, except those before 6 in the morning, and after 6 at night, which must be drawn through the Centre, according to the direction given in Part I. Chap. 3.

It may seem at first something difficult to enter the line of Hours upon your Trigon, between the Hour-lines of 12 and 6, and so as the point 9 or 3 may rest upon the Hour-line of 9 or 3 also; but know there is no difficulty at all, but wonderful easie, and so expeditious, that the Trigon is prepared to prick down all the

Hours, halves and quarters, as soon as you could with your Compasses, take one of them out of a Scale, and will give you the hour points upon the Plain more exact than you can set them well off with the Compasses ---- And farther Note, that your *Trigon* lying in this position, the Line of hours on your *Trigon*, will always lie parallel to the lines E F, and E G, if there be no former error.

Lastly, For the height of the Stile above the Plain (it is in this Example, equal to the Latitude of the place 51 deg. 32 min.) this you may set off by a Line of Chords (as hath been often shewed before) but by the *Trigon* thus ---- Lay the Centre of your *Trigon* upon the point E, the line of Sines lying upon the Meridian (or 12 a Clock) line, then against the Tangent of 51 deg. 32 min. make a mark as H, and draw the line A H for the Stile, so is your Dial finished.

And according to this precept may the Hour-lines upon all *North and South Direct Plains* be drawn, without any farther trouble, and so for such plains, let this one precept suffice.

Section I I.

How to draw the Hour-lines upon the Direct East West upright and Æquinoctial Reclining Plains, by help of the Trigon.

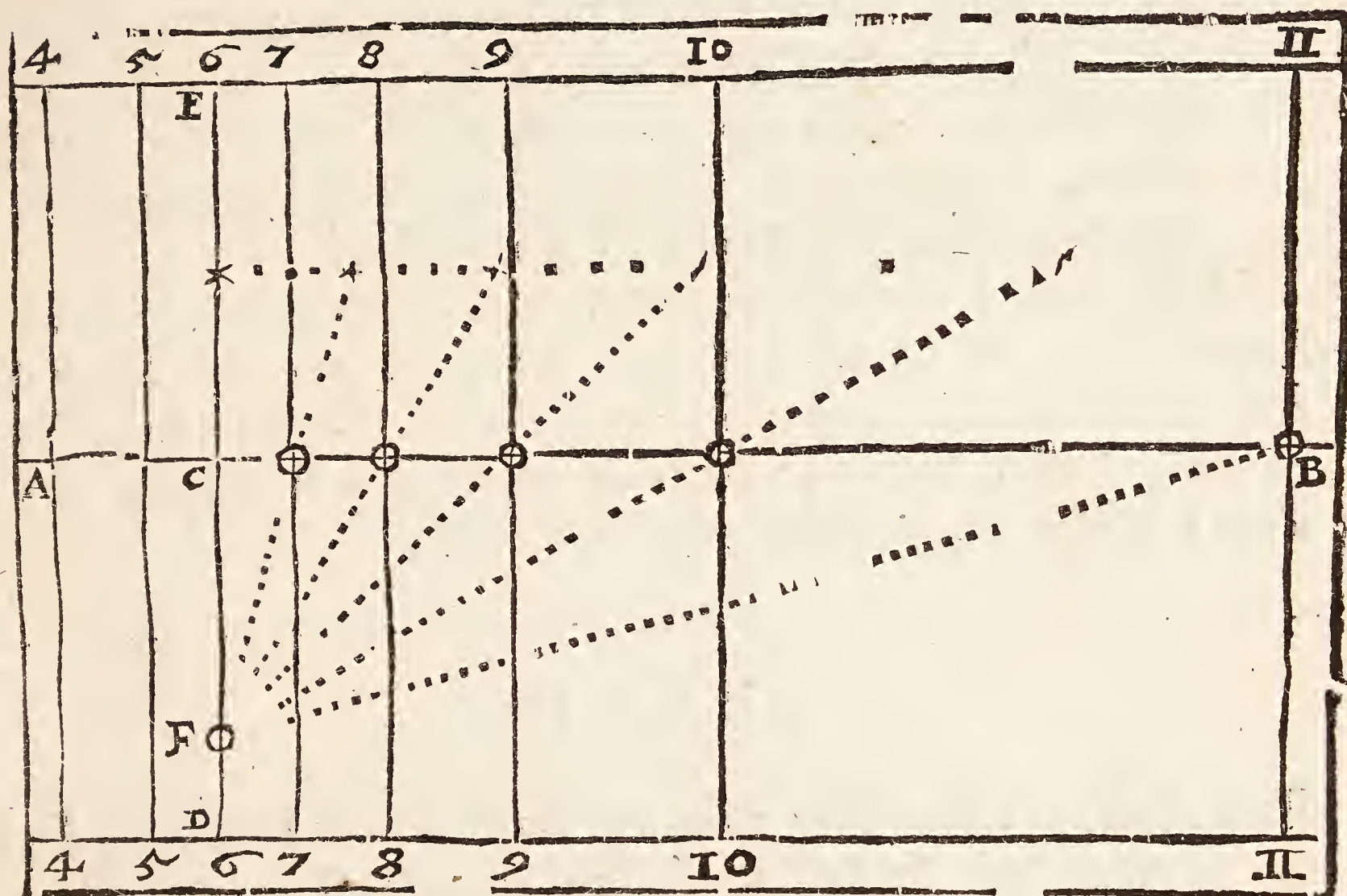
Our Example shall be of an East Erect Direct Plain in the Latitude of 51 deg. 32 min. Wherefore,

First, Draw (by the directions in Part I. Chapter 6. a Right-Line A B for the Æquinoctial, and in any point thereof, as at C, draw a right line D C E (at right Angles thereunto) for the Hour-line of 6.

Secondly, Assign any point of the Hour-line of 6, (proportional to the bigness of your Plain) as F for the height of your perpendicular Stile or Gnomon.

Thirdly,

Thirdly, Lay the *Trigon* to your Plain, so that the Line of Sines may lie just upon the Hour-line of 6, and the end thereof at 90 deg. upon the point F ----- The *Trigon* lying in this position, with your Needle or protracting Pin, make marks upon your Plain, by the side of the Tangent line upon your *Trigon*, at every hour, half and quarter, at the marks *** &c. (for the Tangent line upon the *Trigon*, is divided into hours and parts of time, as well as into degrees and minutes.)



Fourthly, Lay a Ruler to F, and every one of these hours, halves and quarters, and where the Ruler crosseth the *Æquinoctial* Line of the Plain A B, as at the points $\odot \odot \odot$, &c. through those points draw right lines parallel to the Hour-line of 6, and they shall be the true Hours proper for your Plain.

For the hours before 6 in the morning on the *East Dial*, and after 6 at night on the *West Dial*, the same distances set backwards upon the *Æquinoctial*-line, will give you those points as is directed in Part I. Chap. 6.

Note, If you make your Dial answerable to the bigness of your *Trigon*, much of the labour in making of this Dial will be saved : For, when you have drawn A B the *Æquinoctial*, and crossed it at right Angles, with the Line C D E for the Hour-line of 6 ----- Lay the Centre of the *Trigon* upon the point D, and the Tangent line of the *Trigon* upon the *Æquinoctial* Line of the Plain, and so making marks at every hour, half, and quarter, lines drawn through those points parallel to the Hour-line of 6, shall be the true hours proper for the Plain ---- And here note also, that the Line A B first drawn, must make an Angle with the Horizontal Plain, equal to the Complement of the Latitude of the place, for which the Dial is made.

What is said of the East Plain, the same is to be understood of the West, as in Part I. Chap 6. and the same of the *Æquinoctial* Plain also, only the 6 a Clock Hour-line in these Plains, is the 12 a Clock Hour-line in those, as in Part I. Chap. 12 is sufficiently explained.

CHAP. III.

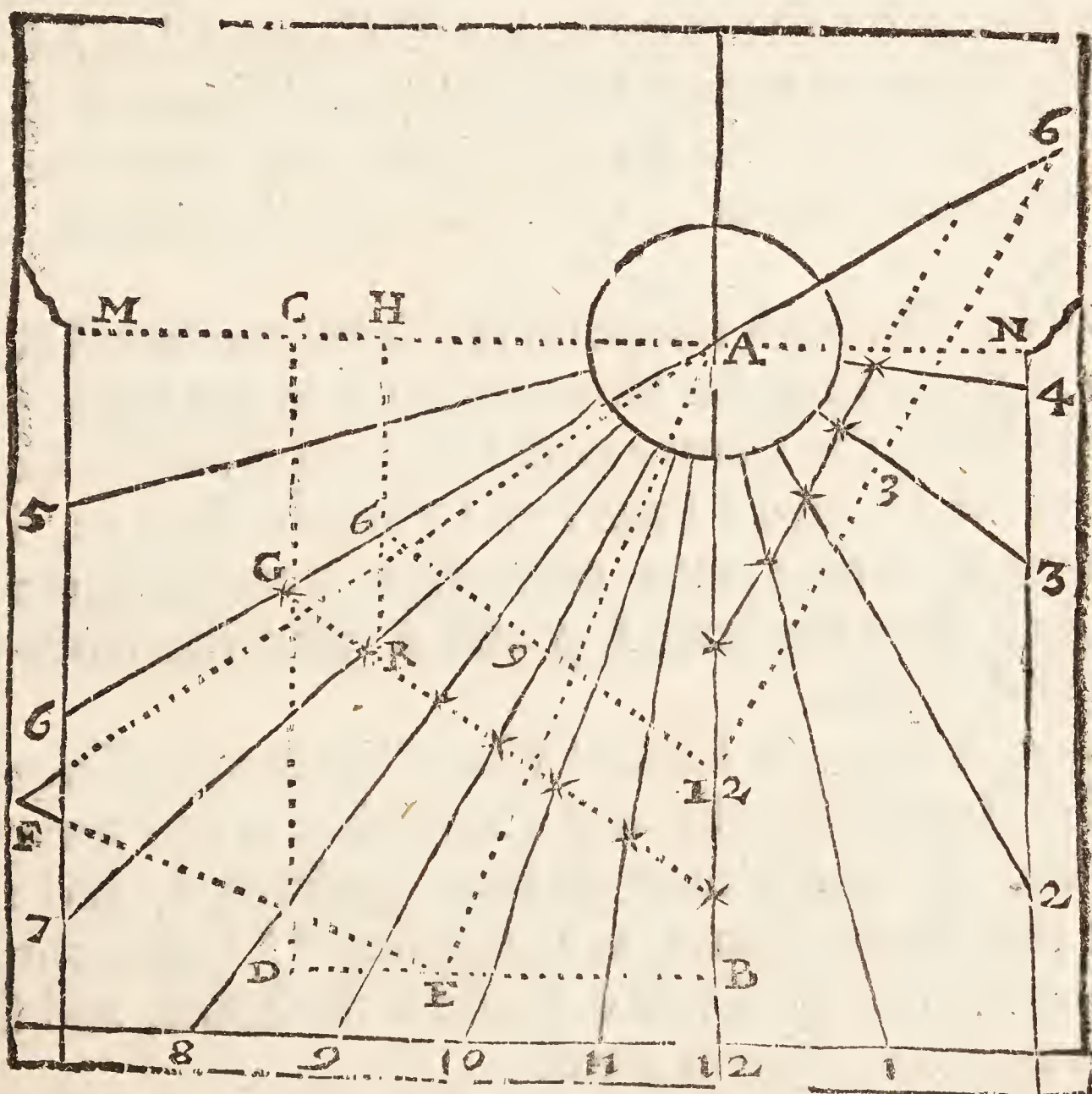
How to draw Hour-lines upon any Erect Plain, Declining East or West, by help of the Horological Trigon.

THese are the Dials, which (of all others) are most in use, and therefore will require the more care in the practice of the making of them; and that I may remove all difficulties that may arise in the making of them at any time, I shall be the more large in this particular, for (indeed) upon the making of these Dials in all Latitudes, doth depend the making of all other Oblique Dials, whether Reclining or Inclining, as hereafter shall be taught.

Section I.

*How to describe the Hour-lines upon an Erect or Upright Plain,
Declining from the South Eastward 30 deg. in the Lati-
tude of 51 deg. 30 min.*

First, Draw a perpendicular or down-right line A 12 B,
for the Meridian and Hour-line of 12, and making choice
of some convenient point therein, as A, for the Centre of
your Dial, draw through that point an Horizontal Line
M A N.



Secondly, Apply the Centre of the Trigon, to the Cen-
tre of the Dial at A, so that the Line of Sines may lie up-
on the Line M A, and the Line of Tangents upon the line
A B: And against the Tangent of the Latitude of the place
51 deg. 32 min. make a mark at B, and also at the Co-Sine
of

of the Latitude 51 deg. 32 min. make another mark at H.

Thirdly, Remove the *Trigon*, laying the Centre thereof to B, and the Line of Tangents upon B A, and against the Sine of the Declination 30 deg. make a mark, as E, and draw the Line A E for the Substilar line of the Dial.

Fourthly, Upon the point E, erect a perpendicular, and laying the Centre of the *Trigon* upon E, and the Line of Sines upon the perpendicular, make a mark against the Co-Sine of the Plains Declination 60 deg. as at F, and draw the Line A F for the Stile.

Fifthly, Laying the Centre of the *Trigon* to B, and the line of Sines upon A B, make a mark against the Co-Tangent of the Latitude of the place 38 deg. 28 min. as at D, and through the point D draw the line D C parallel to A B.

Sixthly, Take in your Compasses the distance B E, and set it upon the line C D from C to G, and draw the Line A G for the Hour-line of 6, quite through the Centre, as the line 6 A 6.

Seventhly, Through the point H, draw the line H R, parallel to A B, cutting the Hour-line of 6 in the point 6, and make A 6 above the Centre, equal to A 6 below the Centre, and the line A 12, equal to E F, drawing the lines 12, 6, and 12, 6, which divide into two equal parts in the points 9 and 3, and draw the lines A 9 and A 3, for the Hour-lines of Nine and Three.

Eighthly, Apply the Line of Hours upon your *Trigon*, between the Hour-lines of 6 and 12, so that 9 and 3 may rest upon 9 and 3 as hath been before prescribed, and make marks at the several hours, as the points *** &c. through which points, and the Centre A, draw the hours, and so the halves and quarters, if you please.

For the line of 5 in the morning, it is drawn by extending the Hour-line of 5 at night through the Centre. And in the making of this Dial, you have made four Dials as is declared, and largely insisted upon, Part I. Chap. 8. and therefore no more need be said of it in this place.

These

These Precepts here delivered, are sufficient for the making of Upright Declining Dials in any Latitude, but most conveniently in these middle Latitudes, under the temperate Zones; in the Torrid and Frigid Zones there may fall out some Inconveniencies, for when the Latitude is either very great or very small, such as the lines on the *Trigon* are not capable to receive, there are other means to remedy those Inconveniencies, which shall be cleared by the two following Propositions, one whereof, shall shew how to effect the work of this Chapter, when the Latitude is very small, the other when it is very great.

Section I I.

P R O P.

To draw an Upright Declining Dial in such a Latitude, where the Pole hath but small Elevation.

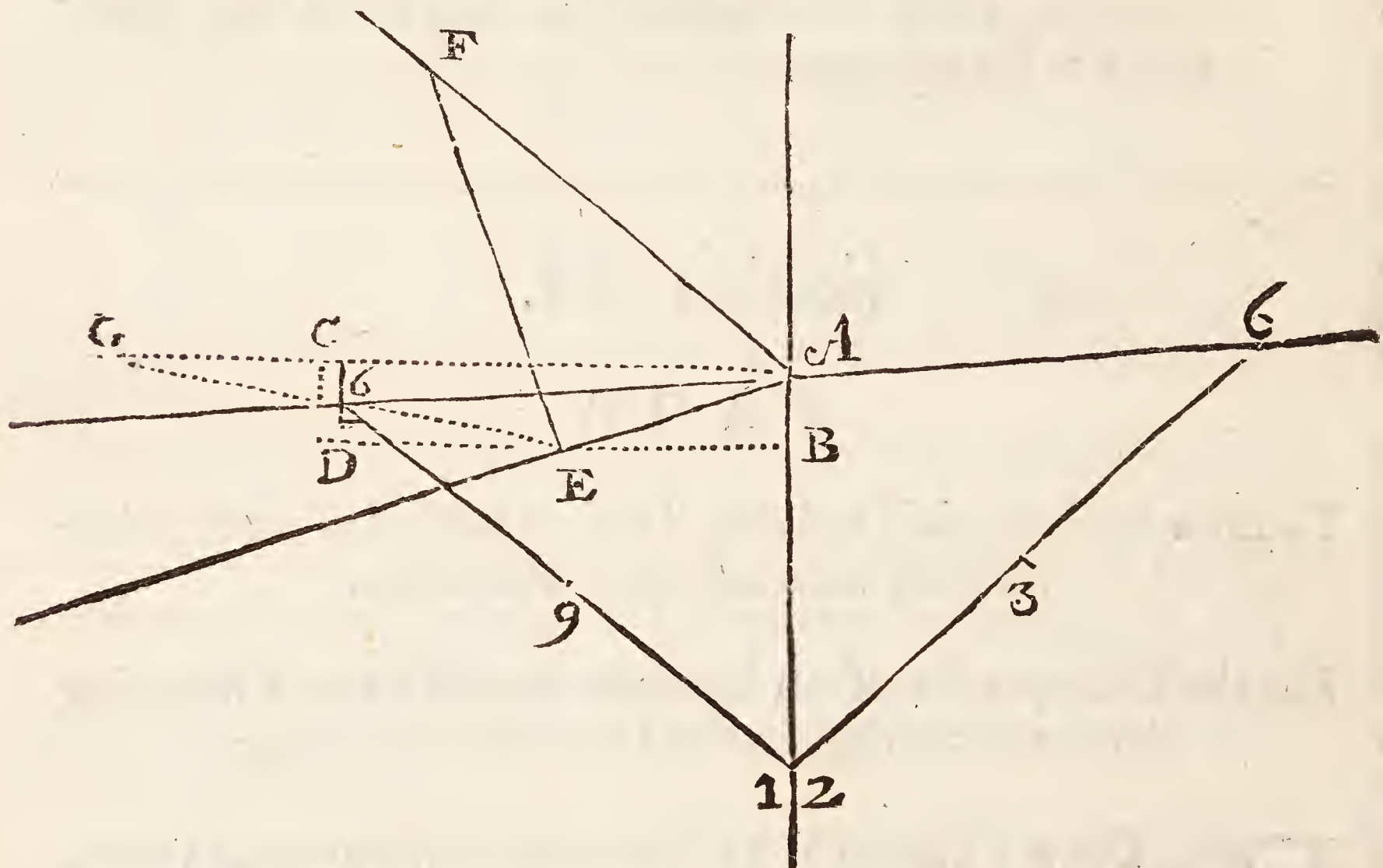
Let the Example be of an Upright South Plain Declining Eastward 30 deg. in the Latitude of 10 deg.

First, Draw a line A B 12, for the Meridian and Hour-line of 12, and make choice of a point therein for a Centre, as A, through which draw a line perpendicular thereto for the Horizontal line of the Plain, as the Line G C A.

Secondly, Lay the Centre of the *Trigon* to the Centre of the Dial, and the Tangent-line thereof upon the Line A B 12. And against 90 deg. or the Radius of the line of Sines, make a mark as C, and also against 80 deg. thereof, which is the Complement of the Latitude of the place, as at H. Likewise against the Tangent of the Latitude 10 deg. make a
T mark,

mark, as at B, and draw the Lines B D parallel to to the Horizontal line G C A, and the line C D parallel to the Meridian Line A B.

Thirdly, Lay the Centre of the *Trigon* upon B, and the Line of Sines upon B D, and make a mark against the Sine of the Plains Declination 30 deg. as E, and draw the Line A E for the Substilar Line of the Dial ; then take the distance B E, and set it upon the Horizontal line of the Plain from C to G, and draw the line E G, cutting the line C D in K, so shall A K be the Hour-line of 6.



Fourthly, Upon the point E, erect the perpendicular E F and laying the Centre of the *Trigon* upon E, and the Line of Sines upon E F, make a mark against the Sine of the Complement of the Plains declination 60 deg. at the point F, and draw the Line A F for the Stile.

Fifthly, Through the point H, draw the line H M, parallel to the line A B, cutting the Hour-line of 6 in the point 6. then taking the distance E F in your Compasses, make the line A 12 equal thereto, and the line A 6 above the Centre equal to A 6 below the Centre, and draw the lines 6, 12. and

and 6, 12. which divide into two equal parts in 9 and 3, and for the other hours apply the line of hours of the *Trigon*, as is before directed, and finish the Dial, according to former Precepts.

P R O P. II.

How to draw an Upright Declining Dial in such a Latitude where the Pole hath great Elevation.

Let the Example be of a South Plain declining Eastward 30 deg. in the Latitude of 80 deg.

F*irst*, Draw a Line A R for the Meridian and Hour-line of 12, and through the Centre A draw the Horizontal Line C A perpendicular thereunto.

Secondly, Lay the Centre of the *Trigon* to the Centre of the Dial, so that the Line of Sines may be upon the Line A B, and the Line of Tangents upon A C, then against the Radius or Sine of 90 deg. make the mark B, and against the Co-Sine of the Plains Declination 30 deg. make the mark 12; also, against the Co-Tangent of the Latitude make the mark or point C, and draw the line C D parallel to A B, and the line B D parallel to C A.

Thirdly, Lay the Centre of the *Trigon* to C, and the line of Sines upon C B, and against the Sine of the Plains declination 30 deg. make the point G, and make B R equal to C G, then draw the Line R G, cutting the line B D in E, so shall A E being drawn be the Substile, and A G the Hour-line of 6.

Fourthly, Take in your Compasses the distance A 12, and set the same from G to P, and from R to T (those Lines being extended) then draw the line T P, cutting the Line D B extended in O, and upon E erect the perpendicular E F equal to E O, and draw A F for the Stile of the Dial.

CHAP. IV.

The Declination and Reclination of a Plain in a known Latitude being given, to find in what Latitude the said Reclining Declining Plain shall be an Upright Plain, and also, what Declination the same shall have in that New Latitude, and how much the Meridian ascends above, or descends below the Horizontal Line of the Plain, and which ways.

SUPPOSE a Plain in the Latitude of *London*, 51 deg. 32 m. should decline Northerly 60 deg. and Recline also 54 deg. (such a Plain is the last Example of North Reclining Declining Plains, in the First Part of this Book.) And it were required to find,

1. In what Latitude that would be an Upright Plain.
And,
2. What Declination it shall have in that new Latitude.
And,
3. How much the Meridian is elevated or depressed above or below the Horizontal Line.

Section I.

To find the New Latitude.

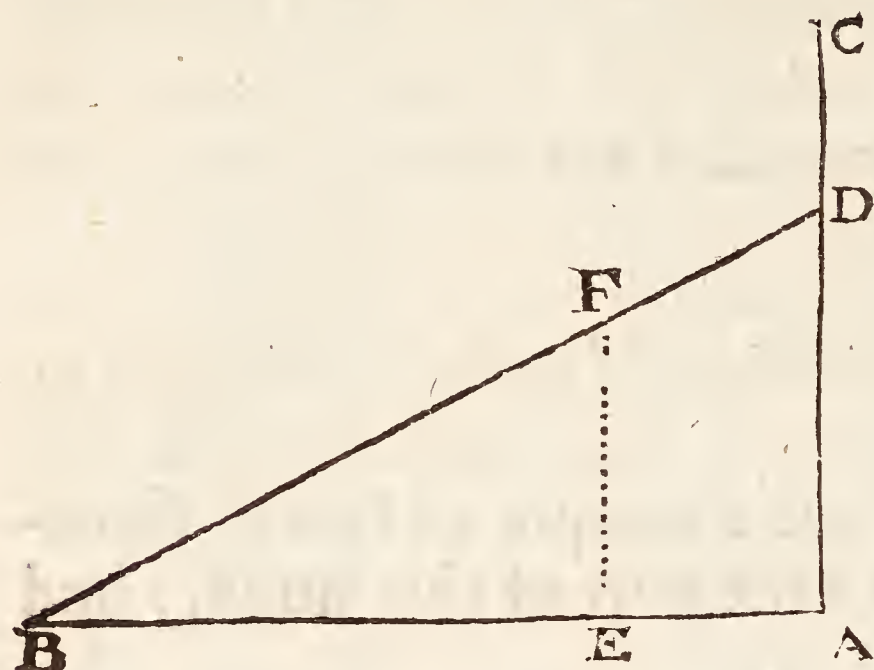
First, Draw a Right-line B A, and at the end thereof A, raise a perpendicular A C.

Secondly, Lay the Centre of the *Trigon* to the point A, so that the Line of Sines may lie upon the Line A C, and the Line of Tangents upon A B. Then,

Thirdly, Make a mark against the Co-Sine of the Plains Declination 30 deg. as D, and another mark against the Radius,

dius or Tangent of 45 as at B — Then turning the Centre of the *Trigon* to B, lay the Tangent line upon B A, and make a mark against the Co-tangent of the Plains Reclination 36 deg. as at E.

Fourthly, Draw the line D B, and apply the Centre of the *Trigon* to E, so that the Line of Sines may lie upon E A: Then will the line



D B lie under the Tangent of 19 deg. 58 min. This Tangent of 19 deg. 58 min. you must compare with the Complement of your old Latitude 38 deg. 28 min. in North Reclining Plains (as in this Example) and

take their difference, which is 18 deg. 30 min. And that is the new Latitude.

And here note, that if the Tangent E F before found prove to be equal to the Complement of your old Latitude, then will your Plain, be a Polar Declining Plain. But again,

In South Reclining Plains, you must compare the Tangent E F with your Latitude, and find their difference, the Complement of which difference shall be your new Latitude.

And *Note* farther, That (in South Recliners,) If the Tangent E F be less than your old Latitude, the contrary Pole is elevated; and if it be equal to your Old Latitude, then it is an *Æquinoctial* Plain.

Section II.

To find the New Declinations.

First, draw a Right Line A B, and upon the point B erect the perpendicular B C.

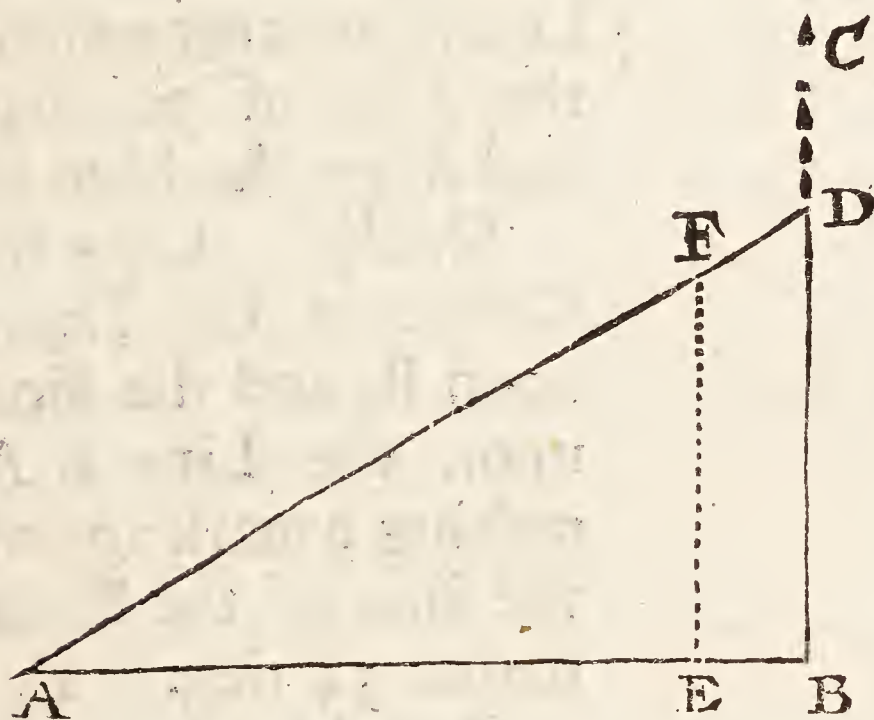
Secondly, Lay the Centre of the *Trigon* to the Point B, so that the Line of Sines may lie upon B C, and the Line of Tangents upon A B, then make a mark against the Tangent of 45 deg. (or the Radius) as at A, and another against the Co-Sine of the Reclination 36 deg. as at D, and draw the Line A D.

Thirdly, Lay the Centre of the *Trigon* upon A, and the Line of Sines upon the line A B, and make a mark against the Sine of the Old Declination (60 deg.) as at E.

Fourthly, Lay the Centre of the *Trigon* to E, and the Tangent line upon A E, so shall the line A D lie just under the Sine of 30 d. 38 min. in the *Trigon*, at the point F, and

this 30 deg. 38 min. is the new Declination.

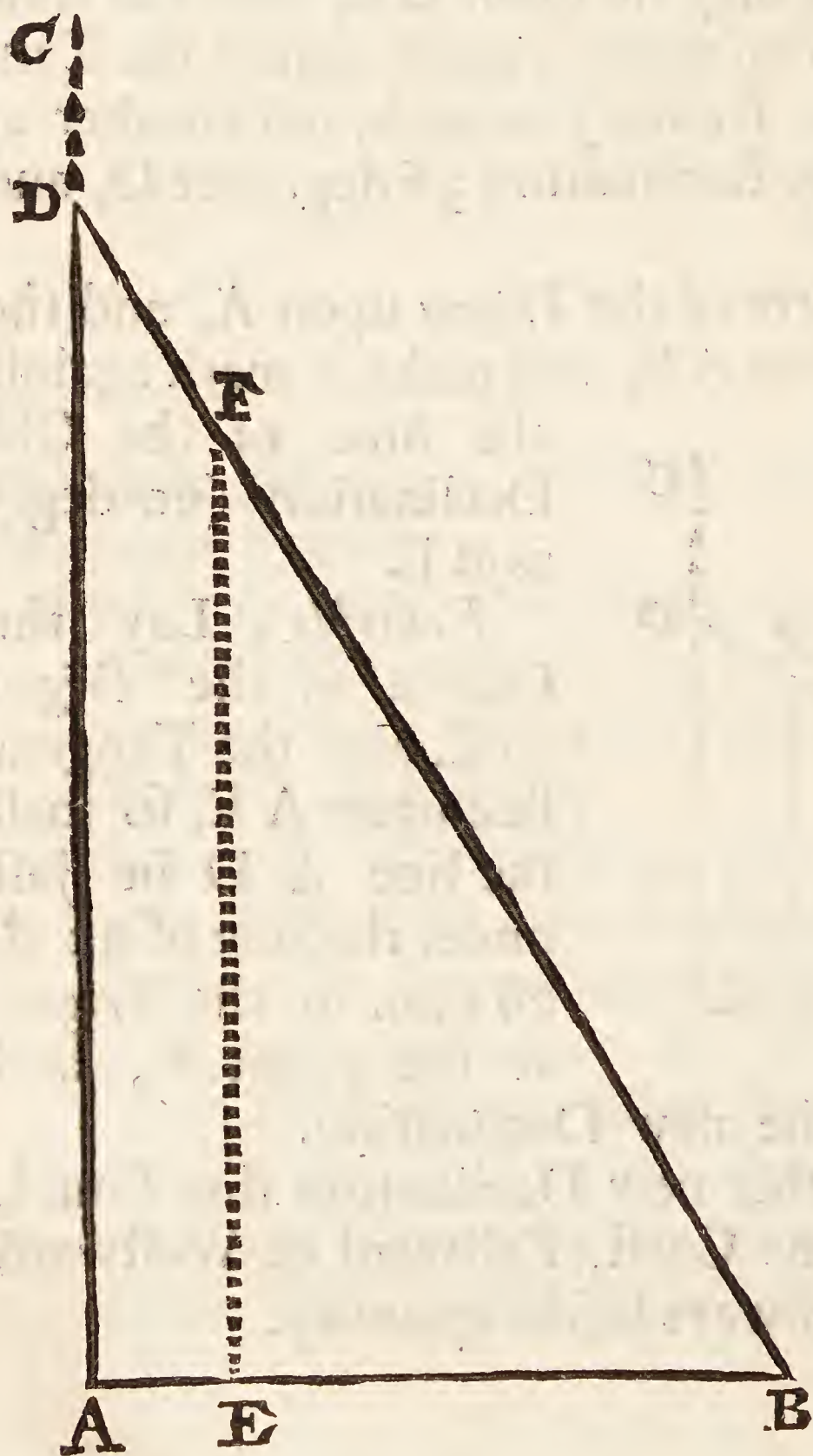
And here note, that this new Declination thus found, is always to the same Coast, Eastward or Westward with the old, but always less in quantity.



Section III.

To find the Angle that the Meridian makes with the Horizontal Line of the Plain.

First, Draw the two Lines A B, and A C, making a right-angle at A.



Secondly, Lay the Centre of the Trigon to A, and the Tangent Line upon A C, and make a mark against the Tangent of the old Declination 60 deg. at D, and another against the Sine of 90 deg. and draw the Line D.

Thirdly, Lay the Centre of the Trigon upon B, and the Sines upon the Line B A, making a mark against the Sine of the Reclination 54 deg. at E.

Fourthly, Lay the Centre of the Trigon to E, and the Sines upon E B, then will the Line B D, lie just under the Tangent of 54 deg. 29 min. which

is the Complement of 35 d. 31 m. and an Angle of that quantity doth the Meridian make with the Horizon.

By these Three Sections of this Chapter, you have reduced

reduced your North Plain, in the Latitude of 51 deg. 32 min.

Reclining 54 deg. 00 min. And
Declining 60 deg. 00. min.

To an Upright Declining Plain in another Latitude,
viz. To

North Plain Declining West
In the Latitude of

	deg.	min.
	30	38
	18	30

So that if by the Precepts delivered in the Third Chapter of this Part, and by the Second Section thereof, because the Latitude is but small, you shall have a true Dial for such a Plain, as declines and reclines the quantities above mentioned in the Latitude of 51 deg. 32 min. Which Dial being truly drawn, and applied to the Reclining Plain, the Meridian making such an Angle as was found by the Third Section of this Chapter, *viz.* 35 deg. 31 min. and placed towards the right Coast (as shall be shewed in the next Chapter) your work is finished, the Precepts here delivered being general.

CHAP. V.

Sewing whether the Meridian Line of the Plain ascends above, or descends below the Horizontal Line of the Plain, and towards what Coast.

THe Third Section of the last Chapter gave you the quantity of this Angle, now for the position of the Meridian line, observe these general Rules following, *viz.*

Latitudes, and so no more need be said of them in this place.

Conclusion.

I Shall conclude this Third Part with these two General and Necessary Rules, teaching,

1. To know which way the Substilar-line of any Dial must stand from the Vertical line of the same Plain. And,
2. How to order your work in the Southern Hemisphere.

For the First,

Upon all Plains whereon the

North Pole	South Pole
------------	------------

is elevated, the Substilar must
lie from the

upper end	lower end
-----------	-----------

of the Vertical line
towards the full

North	South
-------	-------

For the Second.

All the Rules, Precepts and Examples given in this Book, do suppose you to be in the Northern Hemisphere of the World; therefore if you should be in the Southern Hemisphere, these Precepts will serve there also, by only changing the words North and South one into the other, as for South read North, and for North read South, and so Northern for Southern, and the contrary.

The *ART* of
DIALLING,
ARITHMETICALLY

PERFORMED,

By the *CANONS* (or *TABLES*) of Artificial *Sines*
 and *Tangents*.

PART IV.

The Argument.

WHeras the Two foregoing *Geometrical* Ways, and the Third *Instrumental* Way of delineating or making of *Sun-Dials*, may be rejected by some, and a more accurate performance of the same required by others, I thought good (to make this *Treatise* the more compleat, which for a *Geometrical* Way is already perfect enough) to add the *Canons*, *Analogies* or *Proportions*, by which the several *Requisites* in all *Plains* may be *Arithmetically* attained, by help of the *Canons* or *Tables* of Artificial *Sines* and *Tangents* (then by which there can no exacter way.) Which *Tables* are already in every mans hands, and the general use of them no less common: wherefore I shall say nothing of that in this place, but proceed to the finding the forementioned *Requisites*, as followeth. And,

Section

Section I.

Of (Vertical or) Horizontal Plains.

IN these Plains there is nothing required but the *Height of the Pole above the Plain*, which, in all Places, is equal to the Latitude of the Place, for which the Dial is to be made.

Section II.

Of North and South Erect Direct Plains.

IN these Plains also there is nothing required but *The height of the Pole above the Plain*, which in all places is equal to the Complement of the Latitude of the Place. Wherefore, Subtract the Latitude of the Place, for which your Dial is to be made from 90 deg. and the Remainder is the height of the Pole above the South or North Erect Direct Plain.

	deg.	min.
From	90	00
Subtract Latitude	51	32

There remains	38	28

Which is the height of the the Pole above a Direct North or South plain in the Latitude of 51 deg. 32 min.

Section III.

Of North and South Erect Declining Plains.

BUt in Erect Declining Plains, (besides the Latitude of the place, and the Declination of the Plain) there are
three

three things requisite to be found, before you draw the Dial, and they are,

1. The height of the Stile (or Pole) above the Plain.
2. The distance of the Substile from the Meridian.
3. The Plains difference of Longitude.

Example, In the Declining plain in Chapter 8. whose Declination was 24 deg. 20 min. in the Latitude of 51 deg. 32 min.

1. For the height of the Pole above the Plain.

As the Radius 90 deg. 10.000000
Is to the Co-sine of the Latitude 38 deg. 28 min. 9.793831

So is the Co-Sine of the Declination 65 d. 40 m. 9.959596

To the Sine of 34 deg. 33 min. 19.753427

Which 34 deg. 33 min. is the height of the Pole above the Plain.

2. For the distance of the Substile from the Meridian.

As the Sine of 90 10.000000
Is to the Sine of the plains Declination 24 deg. 20 min. } 9.616059

So is the Co-tangent of the Latitude 38 d. 28 m. 9.900086

To the Tangent of 18 deg. 10 min. 19.516145

Which 18 deg. 10 min. is the distance of the Substile from the Meridian.

3. For the Plains difference of Longitude.

As the Co-Sine of the Latitude 38 deg. 28 m. 9.793831

Is to the Radius 90 deg. 10.000000

So is the Sine of the distance of the Substile from the Meridian 18 deg. 10 min. } 19.493851

To the Sine of 30 deg. 00 min. 9.6699201

Which 30 deg 00 min. is the Plains difference of Longitude.

Section I V.

Of South Direct Reclining Plains.

IN these Plains, (the Latitude of the place, and the Reclination of the Plain being given) there is only required *The Height of the Pole above the Plain*: In which there are Three Cases, in all which you may find the Stiles height, as followeth:

1. If the Reclination of the plain be less than the Complement of the Latitude of the place, subtract the Reclination out of the Complement of the Latitude, and the remainder will be the height of the pole or Stile above the Reclining plain. But,
2. If the Reclination of the plain be more than the Complement of the Latitude, subtract the Complement of the Latitude from the Reclination, and the Remainder shall be the Elevation of the pole above the Plain.
3. If the Reclination be equal to the Complement of the Latitude, the pole hath no Elevation over such a plain, but is an *Æquinoctial* plain, and must be made by the Rules delivered in the Twelfth Chapter of the First Part of this Book.

		deg.	min.
1. Case	Latitude 51 deg. 32 min. Comple.	38	28
	Reclination	22	10
	Height of the pole above the Plain	16	18
2. Case	Reclination	62	23
	Latitude 51 deg. 32 min. Comp.	38	28
	Height of the pole above the plain	23	55

Section V.

Of North Direct Reclining Plains.

IN these Plains also (the Latitude and Reclination being given) there is only required *The Height of the Pole above the Plain.*

To find this,

1. Add the Complement of the Latitude to the Reclination, and the sum of them is the height of the Pole above the Reclining plain.

	deg.	min.
Latitude 51 deg. 32 min. Compl.	38	28
Reclination	27	12
	<hr/>	

Height of the Pole above the Plain. 65 40

2. But if this Sum exceed 90 deg. then subtract it from 180 deg. and the remainder shall be the height of the Pole above the Plain.

	deg.	min.
Latitude 51 deg. 32 min. Complent	38	28
Reclination	70	42
	<hr/>	

	sum.	
Which subtract from	180	00
There remains	70	50

Which 70 deg. 50 min. is the height of the Pole above the Plain.

3. If the sum of the Complement of the Latitude, and the Reclination added together do make just 90 deg. then that plain is a Polar Plain, and the Dial for such a Plain must be made in all respects as is directed in the 16. Chapter of the First Part of this Book.

Section V I.

Of East and West Direct Reclining Plans.

IN East and West Reclining Plains (the Latitude of the place, and Reclination being given) there are required the same three things as in North and South Erect Decliners, namely,

1. *The Height of the Pole (or Stile) above the Plain.*
2. *The distance of the Substile from the Meridian.*
3. *The Plains difference of Longitude.*

Example, Of the East or West Reclining Plain Part I.

Chap. 10. whose Reclination was 35 deg. 00 min. and Latitude 51 deg. 32 min.

1. *For the height of the Pole (or Stile) above the Plain.*

As the Radius 90 deg. 10.00000

Is to the Sine of the Latitude 51 deg. 32 min. 9.89347

So is the Sine of the Reclination 35 deg. 9.75859

To the Sine of 26 deg. 41 min. 19.65206

Which 26 deg. 41 min. is the height of the Pole above the Reclining Plain.

2. *For the distance of the Substile from the Meridian.*

As the Radius 90 deg. 10.00000

Is to the Tangent of the Latitude 51 d. 32 m. 10.09991

So is the Co-fine of the Reclination 35 deg. 19.91336

To the Tangent of 45 deg. 52 min. 10.01327

Which 45 deg. 52 min. is the Substiles distance from the Meridian.

3. *For the Plains difference of Longitude.*

As the Sine of the Latitude 51 deg. 32 min. 9.89374

Is to the Radius 90 deg.	10.00000
So is the Sine of the Substiles distance } from the Meridan 45 deg. 52.	19.85595
To the Sine of 66 deg. 27 min.	9.96221
Which 66 deg. 27 min. is the Plains difference of Longitude.	

Section VII.

Of South and North Declining Reclining Plains.

IN Declining Plains Reclining (besides the Latitude of the place, Declination and Reclination of the Plain; which are for most part given) there must four things be found before you can draw the Dial, *viz.*

1. *The distance of the Meridian and Horizon.*
2. *The height of the Pole or Stile.*
3. *The distance of the Substile from the Meridian.*
4. *The Plains difference of Longitude.*

Of these Plains you have in the 20, 21, 22, 23, 24, and 25. Chapters of the First Part Six Varieties, which are all that in any case may happen, *viz.* Three of South Declining Reclining, and as many of North Declining Reclining. I shall only instance in two of them, *viz.* one of a South Reclining Plain Declining Easterly, and another of a North Reclining Plain Declining Westerly. The Example of the South Recliner shall be that in the third and last Variety of South Decliners Reclining, and that is of a South Plain declining Easterly 30 deg. and Reclining 55 deg. as in Part I. Chap. 22.

I. In South Decliners Reclining.

1. For the distance of the Meridian from the Horizon.

As the Radius 90 deg.

10.000000

Is to the Sine of the Reclination 55 deg.

9.91336

So is the Tangent of the Declination 30 deg.

9.76144

To the Tangent of 25 deg. 19 min.

19.67480

Which 25 deg. 19 min. being taken from 90 deg. leaves
64 deg. 41 min. the distance of the Meridian from
the Horizon.

2. For the Height of the Pole (or Stile) above the Plain.

This will require two Operations

1. As the Radius 90 deg.

10.000000

Is to the Sine of the distance of the Me-
ridian from the Horizon 64 d. 41 min. }

9.95615

So is the Co-Sine of the Reclination 35 deg.

9.75859

To the Sine of 31 deg. 14 min.

19.71474

Which 31 deg. 14. min. being less than the Latitude
51 deg. 32 min. subtract it therefrom, and there will
remain 20 deg. 18 min.

Then say again,

2. As the Sine of the distance of the Meridi-
an from the Horizon 64 deg. 41 min. }

9.95615

Is to the Sine of the Arch last found 20 d. 18 m.

9.54025

So is the Co-Sine of the Declination 60 deg.

9.93753

19.47778

To the Sine of 19 deg. 25 min.

9.52163

Which 19 deg. 25 min. is the height of the pole or Stile
above the Plain.Note, That if the Arch found at the first of these Operati-
ons be equal to the Latitude of the place (as there it

was

was lesser, viz. but 31 deg. 14 min.) then the Reclining Plain had been an *Æquinoctial Decliner*, and must be made as by the precepts delivered in the 20. Chap. of the First Part.

3. *For the distance of the Substile and Meridian.*

As to the Co-Tangent of the Declination 60 d. 10.23856

Is to the Sine first found in the last proportion, viz. 31 deg. 14 min. 9.71477

So is the Tangent of the height of the Pole above the plain 19 deg. 25 min. 9.54714

19.26191

To the Sine of 6 deg. 2 min.

9.02335

Which 6 deg. 2 min. is the distance of the Substile from the Meridian.

4. *For the Plains difference of Longitude.*

As the Sine of the difference of the Arch first found, and the Latitude of the place, viz. 20 deg. 18 min. 9.54015

Is to the Radius 90 deg. 10.00000

So is the Sine of the Substiles distance from the Meridian 6 deg. 2 min. 19.02335

To the Sine of 17 deg. 38 min. 9.48320

Which 17 deg. 38 min. is the plains difference of Longitude.

II. In North Decliners Reclining.

In all these Plains (as well as in South Recliners) four things must be found (besides the Latitude of the place, and the Reclination of the Plain, which are commonly given) before the Dial can be drawn, and those are the same as in South Recliners, viz.

1. *The distance of the Meridian from the Horizon.*

2. *The height of the Pole or Stile above the Plain.*

3. *The*

3. The distance of the Substile from the Meridian.
4. The Plains difference of Longitude.

All these may be found by the following *Canons* or *Analogies*. And for an Example, I shall make use of the North Plain Declining Westerly 60 deg. and Reclining 54 deg. as in the last Example of North Recliners, Part I. Chap. 25.

1. For the distance of the Meridian from the Horizon.

As the Radius 90 deg. 10.000000

Is to the Sine of the Reclination 54 deg. 9.90795

So is the Tangent of the Declination 60 deg. 10.23856

To the Sine of 70 deg. 48 min. 9.97306

To the Tangent of 54 deg. 29 min. 10.14651

Which 54 deg. 29 min. being taken from 90 deg. leaves 35 deg. 31 min. And that is the distance of the Meridian from the Horizon.

2. For the height of the Pole (or Stile) above the Plain.

This also will require two Operations.

1. As the Sine of the Declination 60 deg. 9.93753

Is to the Radius 90 deg. 10.000000

So is the Co-Sine of the distance of the Meridian from the Horizon 54 d. 29 m. 19.91059

To this Sine of 70 deg. 2 min. add the Complement of the Latitude 38 deg. 28 min. the sum will be 108 d. 30 min. and this Arch (being above 90 deg.) take it from 180 deg. so will there remain 71 deg. 30 min.

2. As the Sine of the Arch first found 70 d. 2 m. 9.97306

Is to the Sine of the Reclination 54 d. 0 min. 9.90796

So is the Sine of the Arch last found 71 d. 30 min. 9.07695

To the Sine of 54 deg. 43 min. 19.88491

9.91185

Which

Which 54 deg. 43 min. is the height of the Pole or Stile above the Plain.

Note, That if the Arch first found, viz. 70 deg. 2 min. had been just 90 deg. the plain then had been a polar declining Plain, the Substile and the hour of six being the same, and must be made by the Precepts delivered in Part I. Chapter 23.

3. *For the distance of the Substile and Meridian.*

As the Tangent of the Reclination 54 deg. 10.13874

Is to the Sine of the Arch first found } 9.91059
viz. 54 deg. 29 min. }

So is the Tangent of the height of the } 10.15021
 pole above the plain 54 d. 43 min. }

20.06080

To the Sine of 56 deg. 42 min. 9.92206

Which 56 deg. 42 min. or rather the Complement thereof to 180 deg. *viz.* 123 deg. 18 min. is the distance of the Substile from the Meridian, according as you please to account it, either from the North, or from the South.

4. *For the Plains difference of Longitude.*

As the Sine of the height of the pole above } 9.91184
 the plain 54 deg. 43 min. }

Is to the Tangent of the distance of the Sub- } 10.18251
 stile and Meridian 56 deg. 42 min. }

So is the Radius 90 deg. 10.00000

To the Tangent of 61 deg. 48 min. 10.27067

Which 61 deg. 48 min. is the plains difference of Longitude counted from the North, or the Complement thereof to 180 deg. *viz.* 118 deg. 12 min. is the same difference of Longitude counted from the South.

Section VIII.

Of the Hour Distances upon the Plains.

Hitherto you have in a general, plain, and easie Method (and of all others the most exact) delivered, the manner how to calculate the requisites belonging to all sorts of Plains whether *Direct*, *Reclining*, *Declining*, or *both*. It resteth now, to find the true hour distances one from another upon any of these Plains, and for that (for all Dials which have Centres) there is only one general *Analogy* or *Proportion*, and that is this. Having found the *Plains difference of Longitude* ; say,

As the Radius or Sine of 90 deg.

Is to the Sine of the height of the Pole or Stile above the Plain.

So is the Tangent of each hours distance (upon the *Æquinoctial*) from the Substile,

To the Tangent of the same hours distance upon the plain counted for the Substile.

Now, (because Examples do more confirm than barely Precepts) I shall by President or Example make plain all that hath hitherto been delivered, and one shall serve instead of many, and that shall be in an Upright or Erect Declining plain, (which of all Dials are the most common and useful.) Suppose therefore,

In Latitude 52 deg. 40 min. an Erect Plain beholding the South, to decline Westward 24 degrees,

The Arithmetical Calculation.

By the Rules delivered in the III. Section of these Precepts, you shall find,

1. The height of the Pole (or Stile) above the Plain to be 33 deg. 38 min.

2. The distance of the Substile from the Meridian to be 17 deg. 14 min. And,

3. The Plains difference of Longitude to be 29 deg. 15 min.

These Requisites being thus attained, the next thing is to find the hour distances upon the Plain, which may be done by the last foregoing *Analogy*.

But first, you are to consider the quantity of the Plains difference of Longitude, which here, in this Example, is found to be 29 deg. 15 min. And because every hours distance upon the Equinoctial is 15 deg. distance from the Substile, or Meridian of the Plain; so 2 hours is 30 deg. distance, and 3 hours is 45 deg. distance: This Plains difference of Longitude being above 15 deg. (which is one hours distance) and less than 30 deg. (which is two hours distance) the Substile (the plain declining Westerly) must needs fall between the hours of 1 and 2 in the Afternoon. Wherefore subtract 15 deg. (1 hours distance) from 29 deg. 15 min. and there will remain 14 deg. 15 m. the Equinoctial distance of 1 a clock from the Substile. Also from 30 deg. (which is two hours distance) subtract 29 deg. 15 m. and the remainder will be 00 deg. 15 min. for the Equinoctial distance of 2 a clock from the Substile. Having found the Equinoctial distances of the two next hour-lines on either side of the Substile (as of 1 and 2) the rest are easily found by the continual addition of 15 deg. and so is the Column of the Equinoctial distances in the following Table made. Being thus prepared, the true hour distances from the Substile upon the Plain may easily be attained by the foregoing *Analogy*. I will instance in one hours distance for all, and give you the rest in a Table: As,

Let it be required to find the distance of one a Clock upon the Plain from the Substile, Say,

As the Sine of 90 deg.

10000000

Is to the Sine of the height of the Stile }
33 deg. 38 min. }

9.74341

So is the Tangent of the Equinoctial distance }
of one a clock, viz. 14 deg. 15 min. }

9.40478

To the Tangent of 8 deg. 0 min.

19.14819

Which 8 deg. 0 min. is the distance of the one a clock hour-line upon the Plain from the Substile. And in the same manner may you find the distance of 2 a Clock to be 0 deg. 25 min. Of 3 a clock 8 deg. 53 m. Of 4 a Clock 18 deg. 14 min. and so the rest, as in the following Table for every whole hour. And if you desire halves and quarters of hours, you must insert them in the Column of Equinoctial distances, allowing 7 deg. 30 min. for half an hour, and 3 deg. 45 min. for a quarter, and so 15 deg. for a whole hour.

	Equinoctial distances		True hour distances	
	deg.	min.	deg.	min.
VIII	89	15	88	39
IX	74	15	63	1
X	59	15	42	57
XI	44	15	28	21
XII	29	15	17	14
I	14	15	8	0
Substile			Substile	
II	0	45	0	25
III	15	45	8	53
IV	30	45	18	14
V	45	45	29	37
VI	60	45	44	41
VII	75	45	65	22

Thus

Thus have you the Arithmetical Calculation of the whole Dial; it remains now to shew how these hour-lines are to be transferred from the Table to the Dial-plain, which is to be done as followeth.

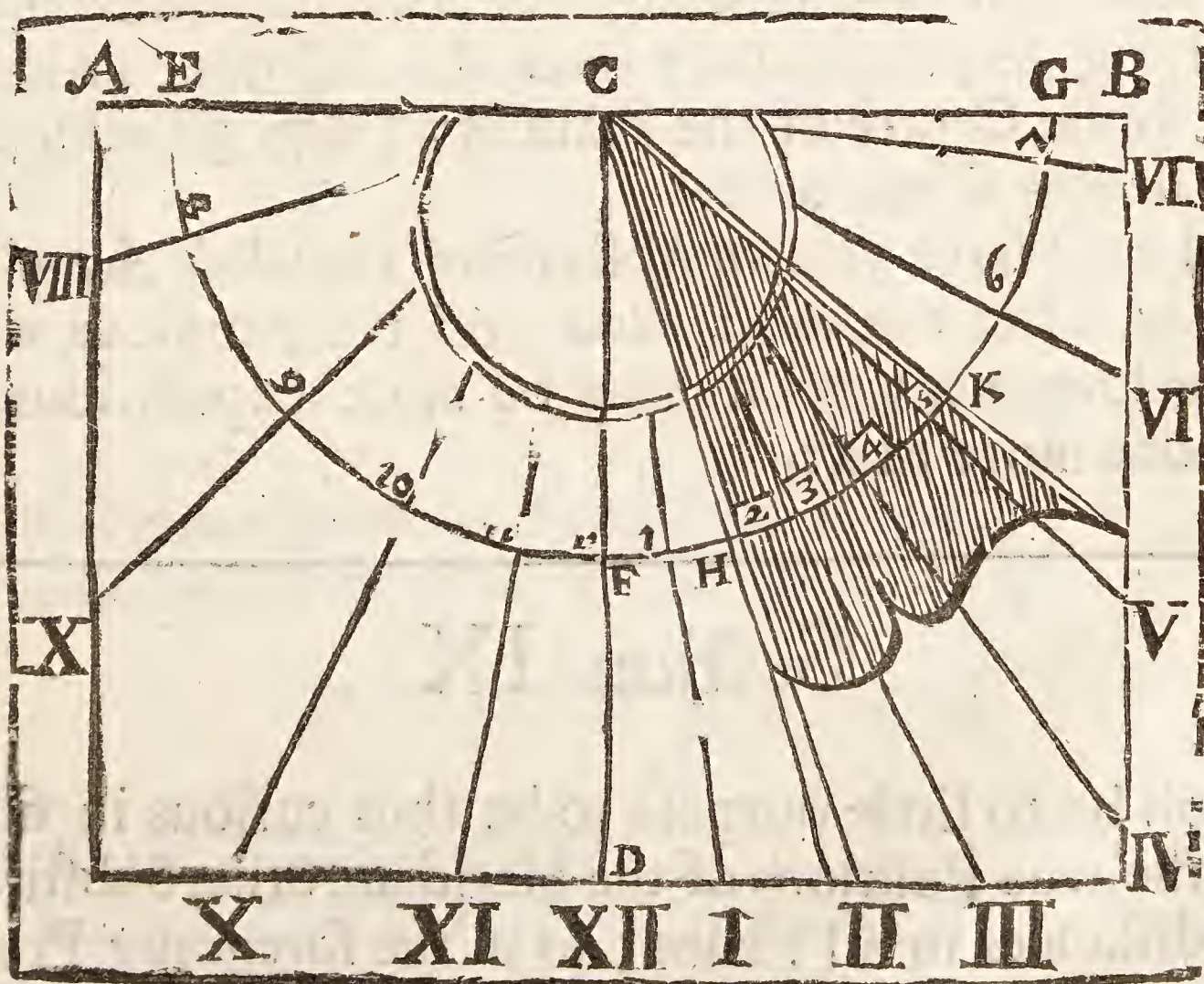
The Geometrical Projection.

First, (Upon your Dial-plain) draw an Horizontal-line A B, and perpendicular thereunto another line C D, for the Meridian and Hour-line of 12.

Secondly, Take 60 deg. out of your line of Chords, and setting one foot in C, with the other describe the Semicircle E F G.

Thirdly, Because the distance of the Substile from the Meridian was found to be 17 deg. 14 min. take 17 d. 14 m. from your Line of Chords, and set them upon the Semicircle from F to H, and draw the Line C H for the Substile.

South Declining West 24 degrees, Latitude 52 deg. 40 min.



Fourthly, The height of the Stile being 33 deg. 38 min. set that distance upon the Semicircle from H to K, and draw the Line CK for the Stile.

Fifthly, (Having recourse to your Table) take 18 deg. 39 min. out of your Line of Chords, and set them upon the Semicircle from H to 8, and draw the line C 8 for the Hour-line of 8 of the Clock.

deg. min.							
<i>Lastly</i> , From your line of Chords, take	63	1	and set the same upon the Semi- circle up- on the Plain, from H, to	9	and draw the lines	C 9	for the Hour-lines.
	42	57		10		C 10	
	18	21		11		C 11	
	17	14		12		C 12	
	8	0		1		C 1	
	0	25		2		C 2	
	8	53		3		C 3	
	18	14		4		C 4	
	29	37		5		C 5	
	44	41		6		C 6	
	65	22		7		C 7	

Thus is your Dial finished, only the Stile, which must be set to hang perpendicularly over the Substile, making an Angle at the Centre of the Plain of 33 deg. 38 min. equal to the height of the Stile.

And thus have you an Abstract of *The whole Art of Dialling*, after the most exact and compendious way of performance; others may be more expeditious, but none more exact.

Section IX.

IT will be to little purpose to be thus curious in finding of the true Positions of the Meridian, Stile, Substile and Hour-distances in all Plains, as in the foregoing Precepts is delivered, unless also we be as severe or strict in finding
of

of the Site or Position of the Plain, upon which the Dial is to be made. For what will it signifie to make the Dial true, and place it in a wrong Position? You are in the Geometrical Part of this Book taught how to find the Declination of any Plain, and for the finding of it, to attain the true *Azimuth* of the Sun is the chief Ingredient, and how to perform that Geometrically, is there taught two ways. But that the like exactness may be in the performance of this also, I shall in this place (before I end) exhibit the manner of finding the Sun's *Azimuth* at any time, and in any place, by Arithmetical Calculation.

Example, In the *Latitude* of 51 deg. 32 min. the Sun having 17 deg. 56 min. of *North Declination*, and his *Altitude* 35 deg. Let it be required to find his *Azimuth*.

First, Add the Complement of the Latitude, the Complement of the Declination, and the Complement of the Sun's Altitude all into one Sum, and take the half thereof, from which half Sum subtract the Complement of the Declination, and note the difference as here is done.

	deg.	min.		deg.	min.
Latitude	51	32	} Complement	38	28
Declination	17	56		72	04
Altitude	35	00		55	00

Summ 165 32

half summ 82 46

The difference between the half summ and the Complement of the Declination. } 10 42

Then will the proportion be

(1.) As the Radius 90 deg.	10.00000
Is to the Co-sine of the Altitude 55 deg.	9.91336
So is the Co-sine of the Latitude 38 d. 28 m.	9.79383
To the Sine of 30 deg. 38 min.	19.70719

(2.) As

(2.) As the Sine of 30 deg. 38 min.	9.70719
Is to the Sine of the half sum 82 d. 46 m.	9.99653
So is the Sine of the difference 10 d. 42 min.	9.26873
	<u>19.26526</u>
To this Sine	9.55807
To which add the Radius or Sine of 90 d.	10.00000
	<u>The Sum is 19.55807</u>
	The half Sum 9.77903

Which is the Sine of 36 deg. 58 min. the Complement whereof is 53 deg. 2 min. and that doubled is 106 d. 4. m. which is the Suns Azimuth from the North part of the Meridian, which if you take from 180 deg. there will remain 73 deg. 56 min. which is the Azimuth from the South. And thus may you find the Sun's *Azimuth* most exactly at any time.

POSTSCRIPT.

IN the foregoing Treatise, you have Four several ways of making all manner of Plain Sun Dials, viz. Two Geometrical, one Instrumental, and a Fourth performed by Arithmetical Calculation: It might here be expected, that I should now shew how to adorn and beautifie these Dials with various Furniture relating to the Sun's Course; I having done something (long since) of that Nature in another place: And to treat of them here, would have much enhaunced the Price of the Book, the Engraving and Printing Copper Schemes being very Chargeable: But to satisfie such as are delighted with Curiosities of this Nature, the Author hereof, hath now in the Press, a Book in Folio Entituled,

AD-

An East Dial
DIAL
with 12 Parallels
of the 12 Signs
and Azimuths.

The Trigon

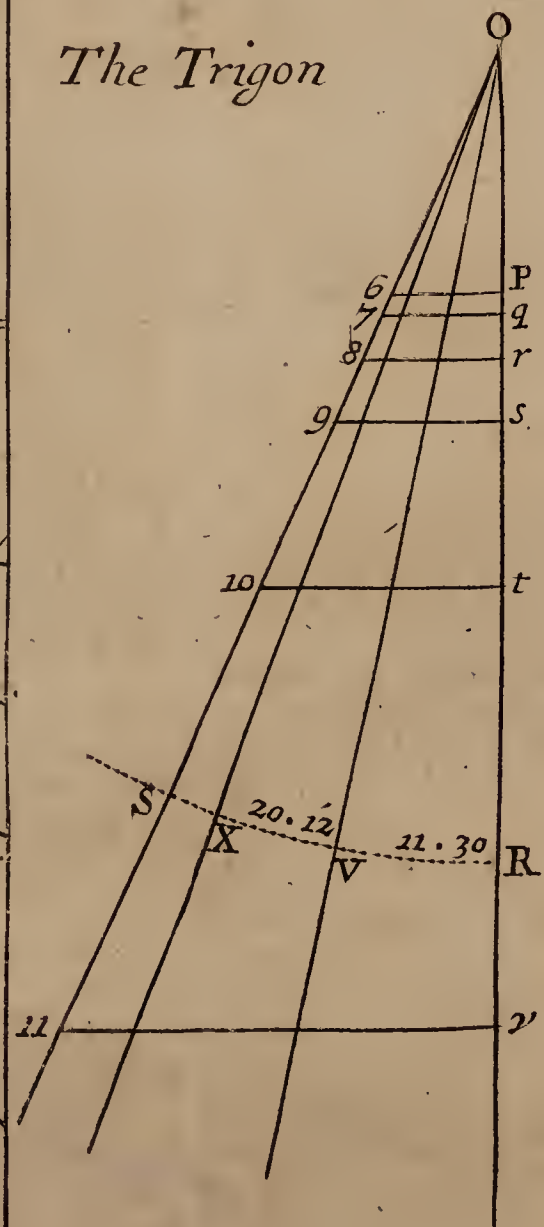


Fig. IV.

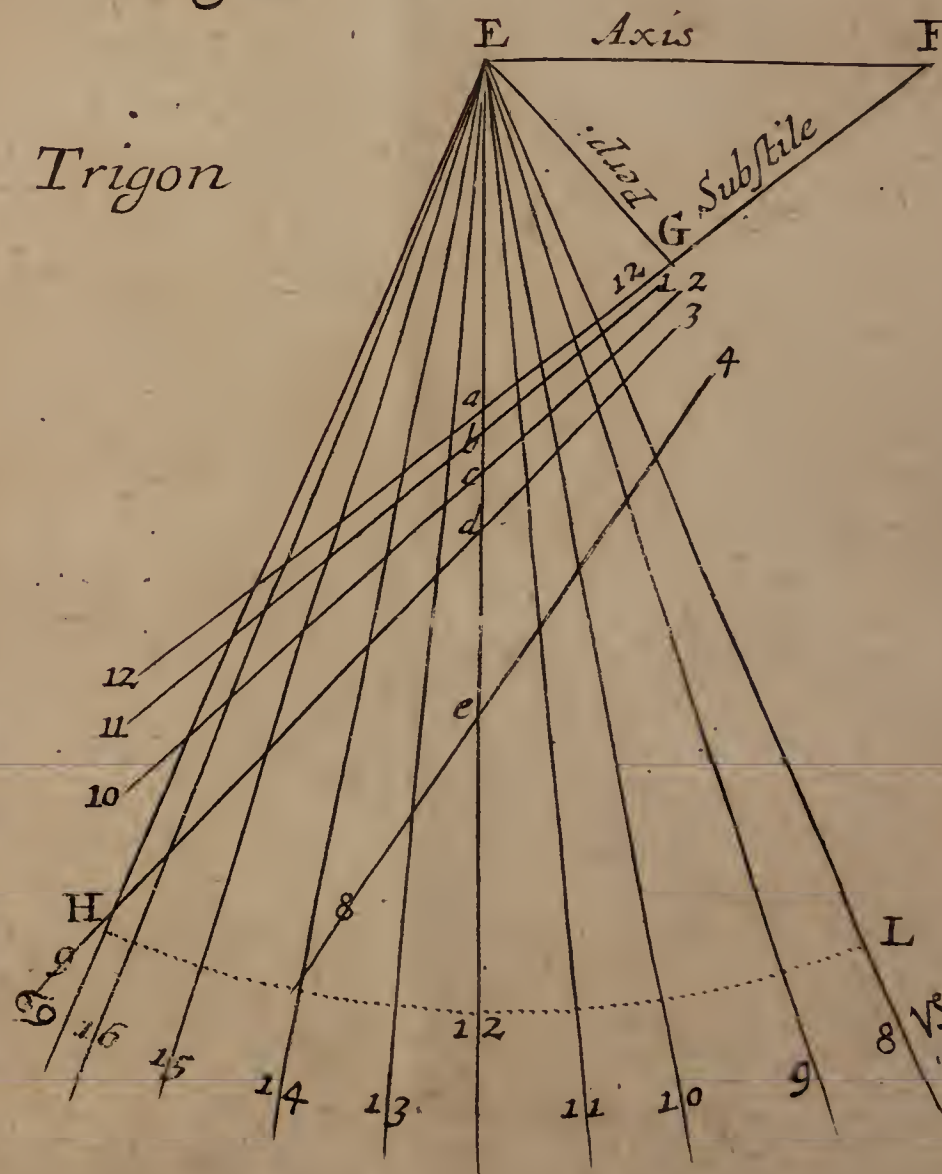




Fig. V.

The diagram is a complex geometric construction, likely a celestial map or a technical drawing of a dome. It features a large circular arc at the top, a central vertical axis, and a series of curved lines radiating from the top. The diagram is divided into sections labeled with Roman numerals (IX, X, XI, XII, I, II, III) and various symbols (e.g., 6, 4, 3, 2, 1, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100). A shaded triangular region is visible in the upper right quadrant.

[illegible][illegible]

(2.) As the Sine of 30 deg. 38 min.

9.70719

Is to the Sine of the half sum 82 d. 46 m.

9.90652

the
Press, a Book in Folio Entituled,

AD-

A
SUPPLEMENT
TO
Geometrical Dialling, &c.

CHAP. I.

*Of such Circles of the Sphere, as are described
upon Sun-Dials.*

MAny *Astronomical* Conclusions may be performed by describing of the *Circles* of the *Sphere* upon *Dial-Plains*; of which I have here made choice of these following:

1. The *Parallels* of the *Signs*, shewing in what part of the *Zodiack* the *Sun* is at all times of the year.
2. The *Diurnal Arches*, shewing the length of the *day* and *night* throughout the year.
3. The *Hours* from the *Sun's Rising*, or *Setting*; or the *Babylonish* and *Italian Hours*.
4. The *Unequal*, *Jewish*, or *Planitary* hours.
5. The *Azimuths*, or *Vertical Circles*, shewing in what quarter of the *World*, or upon what *Point* of the *Mariners Compass*, the *Sun* is at all times of the *Day*.

6. The *Almicanters*, or *Circles of Altitude*; whereby the *Proportion* of *Shadows* to their *Objects*, or the *Sun's height* may be known.

Of these some are *great Circles* of the *Sphere*, others *small*: The *great Circles* in all *Plains* are represented by *streight lines*, as the *hour lines* themselves are: The *lesser Circles* are described by *Conick Sections*; and they are either *Parabolas*, *Hyperbolas*, or *Ellipses*: Only the *Parallels* of the *Signs*, and the *Diurnal Arches* in *Polar Dials*, and the *Parallels of Altitude* in *Horizontal Dials*, and perfect *Circles*.

CHAP. II.

How to describe the Equinoctial, the two Tropicks, and other intermediate Parallels of Declination, upon any Dial Plain.

THe two *Tropicks* being the *Boundaries* of the *Sun's Course*, (for he never exceeds those *Limits*;) I count it best, first to shew how they may be described; for that between them all other *Circles* (either *great* or *small*) must be *projected*, and the manner of describing them upon several *Plains* is various.

In a *Polar Dial* they are perfect *Circles*, and so are easily described by *Circles* drawn about the foot of the *perpendicular stile*; in all other *Plains* they are *Sections* of a *Cone*.

I. In the Equinoctial, and direct East or West Dials.

Let an Example be of a direct *East Dial* in the *Latitude* of 51 d. 32 m.

How to describe the *hour-lines* upon these *Plains* is shewed in the sixth Chapter of this Book. Wherefore such a *Dial*

a Dial being drawn as in Figure I. through the *foot* of the *perpendicular stile* at E, draw a right Line M E N, *Parallel* to the *Horizon*; for the *Horizontal Line*, in all Plains, must be drawn through the foot of the *perpendicular stile*, and also through the Point where the *Equinoctial Circle* crosseth the *Hour-Line* of Six. Your Dial, with the *Equinoctial* Line thereof, H E S, being drawn, come we to describe the *Tropicks*: To effect which,

First, Upon a piece of fine *Card-Paist-Board* draw a right Line O R, as in Figure II. representing the *Equinoctial* Line in your Dial; and (because the *Tropicks* are 23 deg. 30 min. distant from the *Equinoctial*) with 60 deg. of your *Chords*, upon the point O, describe an Arch of a Circle, and upon it set 23 deg. 30 min. from R to S, and draw the Line O S, representing the two *Tropicks*; and this Angle S O R, I call a *Trigon*.

Secondly, Out of your Dial take the length of the *perpendicular Stile* E G, and set it upon the *Trigon* from O to P, and draw the Line P 6 perpendicular to O R: Also

Take the	di-	7	with the Equi-	q	and	q	7	per-
stance from G,		8	noctial,		r		8	pen-
to the Interse-	<	9	set them upon	<	s	>	9	dicu-
ction of the		10	the Trigon		t		10	lar to
Hour-Line of	{	11	from O, to	{	v	}	11	O R.

Having thus prepared the *Trigon*, out of it take the distance P 6, and set it upon the 6 a clock *hour-line*, from E to c: — Also take the distance q 7, and set it upon your Plain from V to b, and from VII to d: — Also take r s, and set it on your Plain from IV to a, and from VIII to e: — Likewise take the distance s 9, and set it upon your Plain from IX to f: — Also take the distance 10 t, and set it from X to g — Lastly, take v 11, and set it on the Plain from XI to h.

These Points *a, b, c, d, e, f, g, h*, are the Points through which the *Tropick of Cancer* must be described; wherefore, if through them a line be drawn with an even hand, making no Angles, that shall be the *Tropick of Cancer*.

The *Tropick of Capricorn* may be described in the same manner, for if from your *Trigon* you take

The distance	{	8	<i>r</i>	{	And set it upon your	{	VIII	<i>k</i>				
		9	<i>s</i>				{	Dial-Plain from	{	IX	<i>l</i>	
		10	<i>t</i>							{	X	<i>m</i>
		11	<i>v</i>									

Those shall be the Points through which the *Tropick of Capricorn* must be described; wherefore if through *k l m n*, a line be drawn with an even hand, it shall represent the *Tropick of Capricorn*:

And whereas I said before, that the two *Tropicks* are the Boundaries of the *Sun's Course*, you are to Note, That

When the Sun is in	{	Capricorn,	{	which is about	{	Decem. 11.	{	the shadow of the top of the <i>Stile</i> will pass along those re- spective Lines.
		Aries, or				March, 10.		
		Libra,				Sept. 12.		
		Cancer,				June, 11.		

And according to this Method may any other intermediate *Parallels of Declination* be inserted; as for *Example*: Suppose I would insert the *Parallels* of the *Sun's* entrance into the 12 Signs, *Aries* and *Libra* are inserted already, also *Cancer* and *Capricorn*; for the rest, as when the Sun enters into

Taurus,

Taurus,
Virgo,
Scorpio,
Pisces,
Gemini,
Leo,
Sagittarius,
Aquarius,

the Sun hath 11 deg. 30 min.
 the Sun hath 20 deg. 12 min.

of Declination,

Wherefore take 11 deg. 30 min. and 20 deg. 12 min. out of your Line of Chords, and set them upon Arch R S of your *Trigon*, from R to V and X, and draw the two Lines O U and O X.

These *Parallels* being thus put into your *Trigon*, they may be transferred into the *Dial Plain*, in all respects, as the *Tropicks* were; and as you see done in the Figure I.

II. In a Direct North or South Dial. Figure III.

Having drawn your *Dial* as is taught in Chapter V. together with the *Stile*, your first work must be to *proportion your Stile to your Plain*; which to doe, assume any convenient point in the *Substile* (here the Line of XII) for the farthermost *Tropick*, as here the Point \mathfrak{E} ; then the *Stile's* height being 38 deg. 28 min. add 23 deg. 32 min. thereto, the Summ is 62 deg. and that is the *Meridian Altitude* of the *Sun* when he enters *Cancer*, and the Complement thereof is 28 deg. wherefore, upon the Point *Cancer*, make an Angle B \mathfrak{E} A to contain 28 deg. so shall the Line \mathfrak{E} A cut the *Axis* of the *Stile* O A, in A; then from A let fall a Perpendicular to O \mathfrak{E} , as A B; and so is your *Stile* proportioned to your *Plain*; and the Line C B D, (being drawn *Parallel* to the *Horizon*, through the Point B) shall be the *Horizontal Line* of the *Plain*.

This done, prepare a *Trigon*, as Figure IV. in which make EF equal to O A, and F G equal to O B, and E G, to A B, the *Triangle* EFG in the *Trigon*, equal to the *Triangle* of the *Stile* O A B in the *Dial*.

From the Point E draw a Perpendicular to EF, as E 12, for the *Equinoctial*; and upon E, with 60 deg. of your *Chord* describe an Arch H 12 L, and upon it set 23 deg. 30 min. from 12 to H and L, & drawing the Line EH for the *Tropick* of *Cancer*, and EL for the *Tropick* of *Capricorn*:

Draw the *Substilar* Line FG quite through the *Trigon*, crossing the *Equinoctial* in *a*, and both the *Tropicks*.

This done, out of your *Trigon* take the distance from F to *a*, and set it upon the *Dial* plain from the Center O to *c*, through which Point *c* draw the right Line $\gamma c \equiv$ for the *Equinoctial*: Then from O, the Center of your *Dial*, take the distance to the intersection of the *Hour-Line* of 11 or 1 with the *Equinoctial*, and set that distance upon the *Trigon* from F to *b*: — Also take the distance from O, to the intersection of the *Hour-Line* of 10 or 2, and set it from F to *c*: — Likewise the distance from O, to the intersection of the *Hour-Line* of 9 or 3, set from E to *d*: — And lastly, the distance from O, to the intersection of 8 or 4, with the *Equinoctial*, set from F to *e*; and draw the Lines F *a*, F *b*, F *c*, F *d*, F *e*, through the *Trigon*, marking them with 12, 11, 10, 9, 8 and 1, 2, 3, 4, &c.

Now to find the Points upon the *Plain*, through which the *Tropicks* must pass;

The Distance from F to	$\left\{ \begin{array}{l} 12 \\ 11 \\ 10 \\ 9 \\ 8 \end{array} \right\}$	will reach from	$\left\{ \begin{array}{l} f \\ g \\ b \end{array} \right\}$	O, the Center of	the <i>Dial</i> , to	$\left\{ \begin{array}{l} e \\ f \\ g \\ b \end{array} \right\}$	on the	Hour-	Lines	of	$\left\{ \begin{array}{l} 12 \\ 11 \\ 10 \\ 9 \end{array} \right\}$	$\left\{ \begin{array}{l} 1 \\ 2 \\ 3 \end{array} \right\}$

Through

Through which points the *Tropick* of *Cancer* must be drawn with an even hand : And,

The dif- stance from F to	{	12	{	will reach	{	12	{	12		
		1		from O, the		k		upon the	11	1
		2		Center of		l		Hour lines	10	2
		3		the Dial,		m		of	9	3
		4		to		8		4		

Through which Points the *Tropick* of *Capricorn* must be drawn. And thus have you the *Equinoctial*, and the two *Tropicks*, described upon a direct South Plain.

III. *How to describe the Equinoctial, and the two Tropicks into any Upright Declining Plain ; or into such as both Recline and Decline.*

Our *Example* shall be in an *Upright Plain*, declining from the *South Westward* 30 deg. The making of these *Dials* is taught in the VII. and VIII. Chapters of this Book : Wherefore, having drawn such a *Dial*, with the *Stile* and *Substile* in a due *Position*, you shall find the height of the *Stile* to be 32 deg. 36 min.

First, Make an *Horizontal Dial* for the Latitude of 32 deg. 36 min. as is the *Declining Dial* Fig. V, where the *Substilar Line* is taken for the Hour-Line of 12, as it is there marked, and the other Pricked-Lines, and the Hour-Lines of an *Horizontal Dial* for the Latitude of 32 deg. 36 min. Now, if according to the directions of the foregoing *Section*, you make a *Trigon*, and insert the *Equinoctial* and *Tropicks*; and afterwards expunge the obscure Lines of the *Horizontal Dial*, the *Equinoctial*, *Tropicks*, and *Horizontal Line* will be the same, as if they had been inserted from the true Hour-Lines belonging to the Plain.

And as the *Tropicks* were described, so likewise may the *Parallels* of the Sun's Entrance into the other Signs, be inserted, if into your *Trigon* you put the *Arches* of their *Declinations* from the *Equinoctial*, namely 11 deg. 30 min. and 20 deg. 12 min. And so are the *Parallels* of the Signs put into this *Dial*, Fig. V —

And in any *Dial* also may the *Diurnal Arches* be described, if you put into the *Trigon* such *Declinations* as the Sun hath from the *Equinoctial*, when the Day is either

		deg.	min.
8	16	23	30
9	15	21	40
10	14	16	55
11	13	11	37
12	12	5	55
		00	00

And so are the *Diurnal Arches* put into the South-Plain, represented by the Pricked lines there, in Fig. III, and the *Trigon* thereunto belonging Fig. IV.

CHAP. III.

How the Hours from the Sun's Rising and Setting are to be inscribed into all sorts of Dial-Plains.

THe *Hours* from *Sun-Rising* are called the *Babylonish Hours*, for that they begin their Day at the Sun's *Rising*; and the *hours* from *Sun-Setting* are called the *Italian hours*, for that in *Italy* they account their *Time* from the *Setting* of the *Sun* the day preceding.

The manner how to inscribe these *hours*, is the same in all Plains, and is easily performed: And because that up-
on

on a full *South*, or *Horizontal Plain*, they will appear most uniform; I have therefore made choice of a direct *South Dial*, as is Fig. III. to inscribe them:

Your *Dial* being drawn, and the *Equinoctial*, $\gamma \approx$, the two *Tropicks*, and $\S \S$, and $\wp \wp$, and the *Horizontal-Line*, *Sun Rise*, *Sun Set*; you must (by the last Chapter) describe two obscure *Parallels of Declination*, one when the Day is 8 hours long, as $\odot 8 \odot$, and the other when the Day is 16 hours long, as $\ast 16 \ast$, the *Equinoctial* being the *Parallel* when the Day is 12 hours long.

Being thus far prepared, the inscription of these *hours* will be very easie; for it is plain, that when the day is but 8 hours long, that the *Sun rises* at 8 in the Morning; and the first line after the *Sun's Rising* is 9 in the Morning; — Also when the day is 12 hours long, the *Sun Rises* at 6 in the Morning, and the first hour after is 7 in the Morning; — Lastly, When the Day is 16 hours long, the *Sun rises* at 4 in the Morning, and the next hour after is 5 in the Morning: — And all the rest as in this Table.

Wherefore, a streight line drawn through the interfections of these hour-lines, with the *Parallels* of 8, 12 and 16 hours, shall be the first hour after the *Sun Rising* all the year long.

In like manner, if you would insert the seventh hour after the *Sun Rising*: By the Table you see, that in the *Parallel* of VIII hours, for the length of the Day, the seventh hour from *Sun Rising* is 3 in the afternoon; therefore observe where the hour-line of 3 crosseth the *Parallel* of VIII hours, which is at *a*. — Also by the Table you see that in the *Parallel* of XII hours, for

		<i>Length of the Day.</i>		
		VIII	XII	XVI
Hours from Sun Rising	I	9	7	5
	II	10	8	6
	III	11	9	7
	IV	12	10	8
	V	1	11	9
	VI	2	12	10
	VII	3	1	11
	VIII	4	2	12
	IX	5	3	1
	X	6	4	2
	XI	7	5	3

the

the length of the day, the seventh hour from *Sun-Rising* is 1 in the Afternoon; wherefore observe where the hour-line of I crosseth the *Equinoctial*, which is at *b*. — Thirdly, By the Table you see, that in the *Parallel* of XVI hours, for the length of the Day, the seventh hour from the Sun's Rising is 11 in the Forenoon; and therefore observe where the hour-line of XI crosseth the *Parallel* of XVI hours, for the length of the day, which is at *c*; so shall a right-line, drawn through these three Points, *a*, *b*, *c*, be the seventh hour after the Sun's Rising throughout the year: And thus by help of this little Table, may all the hour-lines from the Sun's Rising be drawn as you see them drawn, and numbred, as in Fig. III.

In the same manner, as the hours from the Sun's Rising (which are the *Babylonish* hours) were drawn, may the hours from the Sun's Setting (which are the *Italian* hours) be drawn: The difference being only in the numbering of them; the hours from Sun-Rising being numbred from the *West* end of the *Horizontal-line*, by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10: And the hours from Sun-Setting from the *East* end of the *Horizontal-line* backwards, by 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13; all which is evident in the forenamed Fig. III.

C O R O L L A R Y.

The hour-lines from Sun-Rising and Setting being described upon any Dial-Plain, as is before taught, there will by their correspondent intersections one with another, be Points produced, through which if Lines be drawn with an even hand, the same shall be the *Parallels* of the Length of the Day, and such are the Pricked Lines in Figure III, numbred upon the Meridian-Line of the *Dial*, by 8, 9, 10, 11, 12, 13, 14, 15, 16.

CHAP. IV.

Of the Jewish, or Old Unequal, or Planitary-hours, and how they may be inscribed upon any Dial-Plain.

THe Ancients account of their day, was from the Sun's Rising in the Morning, till it's Setting in the Evening, which space of time they did divide into twelve equal Parts, were it long or short : So that in the Summer all that time that the Sun hath *North-Declination*, the hours of their day were longer then a Common equal hour ; and in the Winter, when the Sun hath *South-Declination*, the hours of their day were shorter than a common hour ; but when the Sun is in the *Equinoctial*, their hours are equal to our Common hours.

The Inscription of these hour-lines into all sorts of Plains is very easie, being much like the Inscription of the *Italian* and *Babylonish* hours, taught in the last Chapter.

Having

<i>The Jewish,</i>	<i>The Parallel of 15 hours.</i>		<i>Equinoctial.</i>	<i>The Parallel of 9 hours.</i>	
<i>Hours</i>	<i>Ho.</i>	<i>Min.</i>		<i>Ho.</i>	<i>Min.</i>
I	5	45	7	8	15
II	7	0	8	9	0
III	8	15	9	9	45
IV	9	30	10	10	30
V	10	45	11	11	15
VI	12	0	12	12	0
VII	1	15	1	0	45
VIII	2	30	2	1	30
IX	3	45	3	2	15
X	5	0	4	3	0
XI	6	15	5	3	45
XII	7	30	6	4	30

Having drawn your Dial, with hours, halves, and quarters ; and also the *Equinoctial*, the two *Tropicks*, and *Horizontal Line* ; and also the *Parallels* of the length of the day, as is done in Figure VI, which is a *South Dial* declining *Eastward* 15 deg. you must make choice of two *Parallels* of the length of the Day, which must both of them be equi-

distant from the *Equinoctial*, which let be the *Parallels* of 9 hours, and 15 hours, for those two *Parallels* are most convenient for this purpose ; because the *Jewish* hours in those *Parallels* will justly fall upon the even hours, halves, or quarters : Now the Points through which the *Jewish* hours are to be drawn, this Table will direct to ; wherein you see, that the first *Jewish* hour is to be drawn through 5 hours, 45 min. in the *Parallel* of 15 hours, through 7 in the *Equinoctial*, and through 8 hours and 15 min. in the *Parallel* of 9 hours : — In like manner the second *Jewish* hour must be drawn through the intersection of the 7 hours in the *Parallel* of 15 hours, through 8 in the *Equinoctial*, and through 9 in the *Parallel* of 9 hours : And so must all the rest of them be described as the Table does direct, and as you see done in Figure V. And in this manner, by help of this Table, may they be described in all sorts of Plains, whither *Direct*, *Reclining*, or *Declining*.

CHAP. V.

How the Azimuths, or Vertical Circles, are to be inscribed upon Dial Plains.

THe *Azimuths* are great Circles, and being Projected upon all Plains, become streight Lines; and they are variously described, according as the Plain is situated; particulars of which follow.

SECT. I.

On an Horizontal Plain.

IN these Plains these *Azimuths* are most easily inserted: For, your Dial being drawn; with the *Tropicks* and *Azimuths* thereupon, you have no more to doe, then upon the foot of the perpendicular Stile at O (in Figure VII) as a Centre, to describe a Circle, as S \odot , N \odot , which you may divide into 32 equal Points (beginning at N) answering to the 32 Points of the Mariner's Compass, (or else you may divide it into 90 equal parts, or degrees,) noted with * * *, &c. and through those Points draw streight Lines from O, the foot of the perpendicular Stile, and they shall be the true *Azimuths* upon the *Horizontal* Plain; which you may denominate by *South*, S by E, S S E, S E by S, &c. as you see done in Figure VII.

S E C T. II.

Upon an Erect, Direct East, or West Plain, Figure I.

HAVING made an *East Dial*, and therein inserted the *Equinoctial*, the two *Tropicks*, and the *Horizontal Line*, you may proceed to the *Inscription* of the *Azimuths* in the manner following.

Upon the Point *E*, of the *Horizontal Line* of the Plain *MEN*, erect the Perpendicular *EQ*, equal to *EG*, (the height of the *Stile* of your *Dial*), and upon *Q*, as a Centre, describe the *Quadrant QEL*, and divide it into eight equal parts, representing one quarter of the *Mariner's Compass*, and from *Q*, through those Points, draw Lines to the *Horizontal Line MEN*, noting them with $\odot \odot \odot \odot$ $\odot \odot$; from which Points let fall Perpendiculars from the *Horizontal Line*, and they shall be the *Azimuths* between the *South* and the *East*; — And for those Points which fall between the *East* and the *North*; namely *E by N*, — *ENE*, — *NE by N*, — the same distances being set upon the *Horizontal Line* from *E*, towards the Left hand, as the three first *Azimuths*, *E by S*, — *ESE*, — *SE by E*, were towards the Right hand, shall give the three Points $\odot \odot \odot$ on the Left hand of *E*; through which Points also Lines drawn Perpendicular to the *Horizon*, shall be the *Azimuths*, or Points of the *Compass* between the *East* and the *North*: As in the *Fig. I.* And as the *East Dial* contains the *Azimuths* between the *South* and the *East*: The *West Dial* must contain those between the *South* and the *West*.

SECT. III.

Upon a direct South upright Plain. Figure III.

THe Dial, with the *Equinoctial*, the two *Tropicks*, and the *Horizontal* Line described thereon, the *Azimuths* may be inserted thereon as followeth :

First, Take the length of the *perpendicular Stile* of your Dial A B, and set it upon the *Meridian* of your Dial from B to G.

Secondly, With the distance G B, upon G, describe the *Semicircle* E B F, which divide into 16 equal parts, (if you will,) but I have here divided it but into 8, to shew the manner of the Work, in the Points * * * * &c. through which Points from G, draw obscure lines, extending them till they touch the *Horizontal* Line of the Plain C B D; now if from these Points of touching you draw lines *perpendicular* to the *Horizontal* Line between the *Tropicks*, or *Parallel*, to the line of 12, they shall be the *Azimuths* required.

I have not drawn the lines themselves in this Fig. III. because the Plain is full enough of Lines already.

SECT. IV.

Upon a South Declining Plain. Fig. VI.

AN Example shall be of a *South* Plain, declining Eastward 15 deg.

Such a Dial being drawn, and the *Equinoctial Tropicks*, and the *Horizontal* Line inscribed thereon : Upon the
C Point

Point B of the *Horizontal Line* erect the *perpendicular* B C, equal to B O, the *perpendicular Stile* of your Dial ; upon which Point C describe the *Semicircle* R B S ; which done, lay a Ruler to C, and the Point O, where the hour line of 12 crosseth the *Horizontal Line*, and where the Ruler cuts the *Semi-circle* R B S, at that Point begin to divide it into 16 equal parts, at the Points *** &c. and from the Center C draw lines through those Points, extending them till they touch the *Horizontal Line* D E, in the Points a b c d e f g h i k and l, through these Points right lines being drawn *Parallel* to the *Meridian*, shall be the *Azimuths* desired, which you must number according to the situation of the Plain : Namely, the *Western Azimuths* on the East side of the *Meridian*, and the *East Azimuths* on the West side of the *Meridian*, as you see them numbred in Fig. VI.

CHAP. VI.

How to inscribe the Circles of the Sun's Altitude into Dial-Plains.

THe *Almicanters*, or *Circles of Altitude*, in the *Sphere* have the same habitude to the *Azimuths*, or *Vertical Circles*, as the *Parallels* of declination have to the *Meridians*, or *Hour-Circles* : And therefore, the *Equinoctial* it self, and all the *Parallels* of declination in a *Polar Plain*, and perfect *Circles*, and so are the *Almicanters*, or *Circles of Altitude*, upon an *Horizontal Plain*, as in Fig. VII.

Horizontal Plains, which lie *Parallel* to the *Horizon*, have the *Zenith* for their Poles ; so that for the inscription of them upon these Plains, the foot of the *perpendicular Stile* must be the Centre upon which to describe them.

For

For the *Numeration* of these Circles when they are described, there are two ways most in Use: The one by Degrees and Minutes of the Sun's *Altitude*; the other according to the proportion that the height of any upright *Object* (as a House, Steeple, &c.) bears to the shadow of it: The last of which I have here followed in this Figure VII. where the Circles of *Altitude* are equal, double, triple, and quadruple to the *Altitude* of the perpendicular Stile.

The inscription of these Circles into all other Plains, are, in a kind, the same with the inscription of the *Parallels* of Declination: Only, whereas in inscribing of the *Tropicks*, and other *Parallels* of Declination, you take the Hour-lines out of the Dial-Plain, and put them into a *Trigon*; so in the inscription of these you must take the *Azimuth* Circles out of your Plain, and put them into a *Trigon*, and from thence transfer them back again to your Plain, as in the other: And as the Hour-lines in the other, must be first drawn upon the Plain; so in this must the *Azimuths* be first inscribed: And because these Circles of *Altitude* are smaller Circles of the *Sphere*, as the *Tropicks* and *Parallels* of Declination were, they will upon all Plains (the *Horizontal* excepted) be *Conick* Sections.

CHAP. VII.

A General and Easie way to project Hour-lines upon all kind of Superficies, without any regard had to their standing, either in respect of Declination, Reclination, or Inclination.

IF a Point be assigned upon any Superficies, Flat, or Curved, one or more, wherein the Hour-lines and *Axis* shall concur; how to project the Hours to that Point, and to set up an *Axis* after the ordinary manner to

give shadow to them, without any knowledge how the Dial standeth in respect either of Reclination, Declination, or Inclination.

First, To the Point assigned (upon any side of it) by help of a *Semi-circle*, or other Level, stretch out an *Horizontal* Thred, serving for the *Horizontal*-line; which line need not be one single line, but may be turned at one or more Angles, provided that it lie (all the parts of it) totally in the Superficies of the *Horizon*.

Secondly, With a *perpendicular* thred held up, project the Sun into the assigned Point, and into the *Horizontal* thred, and stick in a Pin, or make a mark upon the same *Horizontal*-line, through which the shadow cutteth, and at the same instant also, take the Sun's *Altitude*.

Thirdly, By the *Altitude* taken find out the Sun's *Azimuth*; this *Azimuth*, what ever it be, is represented by the mark formerly made in the *Horizontal*-line or thred.

Fourthly, Apply a Paist-Board to the assigned Point, and hold it flat, that it may answer to the *Horizontal*-thred also; and upon this Paist-board protract your *Azimuth* by a thred extended from the Point assigned for the Centre to the mark upon the *Horizontal* thred. Which done,

Fifthly, By help of that *Azimuth* upon the Paist-board protract the *Meridian* Line, observing the true Coast, and quantity of the Angle from the *Azimuth*; and to the *Meridian* thus found, describe an *Horizontal* Dial for the Place.

Sixthly, Apply the Paist-board to it's place again, all things standing right as before; project all the Hours into the *Horizontal*-thred from off the Paist-board, and set marks upon the same Line; for the

the Points of each several Hour, which marks may be little Knots to slip too and fro upon the same thred.

Seventhly, Project the *Meridian* Point by a *perpendicular* Thred upon some Object, into that place whereabouts you imagine the *Axis* of the World would pass, above or below, from the Point assigned for the Centre.

Eightly, With your *Semi-circle*, (or a String and Quadrant,) elevated or depressed, (as it shall be required,) from the Point assigned for the Centre, according to your Latitude, project the Pole of the World.

Ninthly, Extend a Thred from the Point assigned for the Centre to the Poles of the World, which shall represent the *Axis*.

Tenthly, By the Point upon the *Horizontal* Thred, and this *Axis*, (either by your Eye, laying the *Axis* to the Hour Points, or laying the Hour Knots to the *Axis*,) you may project all the Hours, and draw them:—— Or else you may let the *Axis* alone, and content your self with the Pole point projected into the *Meridian*: For if from the Point assigned to be the Centre, or meeting of the Hours, and *Axis*, you extend a Thred to each Hour Point in the *Horizontal* Line, and do repose (with your Eye) the same Thred upon the Pole Points; then shall the shadow of the Thred give you that Hour-line; and do so in all the rest.

Eleventhly, Your Thred, or *Axis* lying in it's true situation, you may easily fit an *Axis* to the same posture. If your Dial be described upon a plain Superficies, you may then (by one side of a Square, applied to the Thred, or *Axis*, and the other side lying upon the Plain) find out the *Substile*, and measure from it the Elevation of the *Axis* above the Plain. —— But if

if the Dial be described upon a Curved Superficies, you must be content to set up your *Axis* by the direction of the Thred only.

Twelfthly, This point assigned for the Centre, being a Point of the *Axis*, is, as it were, the *Apex* of the *Griemon*, unto which all the Work is projected: But if it be required to set up an *Axis* to such a Superficies upon which the Hours and *Axis* will not meet in any tolerable manner, because perhaps the *Axis* may be but of very small Elevation above the Superficies, and yet an *Axis* is required, in this case set up any point (of Wire, or such like) of such distance from the Superficies, as that the Hours and *Axis* may be distinct, and through that point let it be required to make the *Axis* pass; you have no more to doe but only to project to this point as before, by letting the shadow of a *perpendicular* thred pass through that point, and noting the same upon the *Horizontal* thred, and counting that end of the Wire as your Centre, proceed as before; for the thred that lies to project the Hours is a pattern for the *Axis*.

This Way is general, serving to project the Hour-lines upon many Superficies, be they Plain or Curved, and however situate, whether contiguous or separate, and that without any laborious inquisition of any of their situations in respect of Declination, Reclination, or Inclination.

CHAP. VIII.

How from a Glass, Horizontally placed, to Reflect-hours upon any Superficies Flat or Curved, one or more.

First, The Glass being placed truly *Horizontal*, observe the spot of Light that the Sun casts, and make a Mark at it.

Secondly,

Secondly, And observe immediately the Sun's *Altitude*, and find the *Azimuth*.

Thirdly, Then extend an *Horizontal* thred in the same Level with the Glass, but within the Room.

Fourthly, Project the *Azimuth* into the *Horizontal* thred, by holding up a *perpendicular* thred in such a place, that though it hang at liberty you may at once discern both the mark of the spot of Light and the Glass likewise; and then observe where the *perpendicular* thred seems to cut the *Horizontal* thred, and at that apparent intersection make a mark upon the *Horizontal* thred for the *Azimuth*.

Fifthly, Apply a Paist-board to the Glass, so that it may be stayed upon some rest, that after it is taken away it may be restored to it's place again with all exactness: Let it be also placed Horizontally, so that it may have full relation to the *Horizontal* thred.

Sixthly, At the Glass's Centre make a point for the Centre upon the Paist-board, and extending a thred from the Centre of the Paist-board to the mark of the *Azimuth* upon the *Horizontal* thred, draw upon the Paist-board that line which the extended thred figures out thereupon; afterwards unto the same *Azimuth* upon the Paist-board draw a *Meridian* line, and to it an *Horizontal-Dial*; and applying the Paist-board again to it's first situation, project the hours thereon unto the *Horizontal* thred, and there make marks, or knots.

Seventhly, Then project the *Meridian* (by a *perpendicular* thred, covering, in appearance, both the Knot at 12, and the Glass) unto the contrary Coast to that wherein the Pole is elevated above the *Horizon*; that is to say, in our Northern Climates, you must project the *Meridian* Southward from the Glass, because the North Pole is elevated: And in the *Meridian*, elevate your *Semi-circle*, or extend a thred and quadrant from the Glass Southwards till the Plummets fall upon your Latitude, so shall it point out, upon some Object set to receive it, the North Pole reflected.

Or

Or else, if this be not convenient (because in Windows which look towards the *South*, the *North* Pole will be without the Room, and so the *Axis* above the Glass extended towards that Pole will be without also) you may in such Cases find out the opposite Pole to it, that is to say, that Pole which the former reflected *Axis*, being extended through the Glass, and below it, would sign out, and that may be effected in this manner.

Eighthly, Project the Meridian Line towards the Pole that is elevated, that is with us, towards the *North* Pole; and then (because the *North* Pole is elevated by reflection towards the *South*, so, by the same reason, the *South* Pole must be depressed towards the *North*) by your *Semi-circle*, or string and quadrant, directed even with the Centre of the Glass, express or project your Latitude downwards, (but towards the *North*,) so shall the *Semi-circle*, or thred, point out the reflected *South* Pole in the Meridian. Now, whether you will, or can, (most conveniently,) use the reflected *North* Pole above the Glass, or the reflected *South* Pole below it, you are to take your Choice, for both the one, and the other of them do represent the reflected *Axis* of the World.

Ninthly, By this reflected *Axis*, and the Hour points signed out upon the *Horizontal* thred, you may easily Project the reflected Hours, upon any kind of Superficies, one or more, whatever they be, that stand in the way.

F I N I S.

